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Alloys Research.*

THE various researches published by the Institute of Mechanical Engineers in the form of reports to the Alloys Research Committee, will be familiar to our readers. The formation of this Committee with the laudable object of advancing our knowledge of industrial alloys promised much of value to the engineering world. The investigations were entrusted to Sir Wm. Roberts Austen and the first five reports embody the result of his work. Owing to his regrettable death, only some ten pages of the recently issued report on "The Heat Treatment of Steel" owe their origin to him, the remainder coming from Professor Gowland supported by the experimental work of Mr. Merritt.

These reports represent a vast amount of original research, the chief value of the earlier investigations lying in the development of pyrometric methods and the introduction of the photographic recorder. Although full of matter of keen interest to the scientific mind, information capable of direct application to problems confronting the metallurgist, is scarce. This may be accounted for by the strongly evidenced desire to make the experimental work fit a preconceived theory. The keynote of the reports is struck in the endeavour to apply the periodic law of Newlands and Mendieleef to the mechanical properties of metals. As is well known this law states the properties of the elements to be a periodic function of their atomic weights. For further convenience it is assumed that chemically pure iron* can exist in two widely different states, viz., α, or the soft ordinary variety, and β or hard variety. Turning to the influence of elements on iron, the periodic law states this influence to be a function of the atomic volume; thus, the smaller the atomic volume of an added element, the greater its power of hardening and retaining the cold metal in the β variety. Elements possessing atomic volumes greater than that of iron tend to maintain the iron at high temperatures in the α or soft condition and must therefore have the same effect on the cold metal.

*"It will be evident that if iron itself can exist in two widely different states, each with properties of its own, the mechanical properties of given samples of iron and steel must depend upon the relative proportions of the two modifications of iron present in the mass."

The following quotation is taken from the recently issued report—

"It is now known that allotropic changes in the iron itself are the all-important factors in determining the relations between iron and carbon which are involved in the characteristic capacity of steel for being hardened and tempered."

These two quotations, from the first

* Sixth Report to the Alloys Research Committee on the Heat Treatment of Steel.

* Page 545, First Report. Oct. 29th, 1891.

and sixth report respectively, emphasise the bias already alluded to. It is not *known* that allotropic changes affect iron in the manner indicated, and as the existence of the hard variety of pure iron has not yet been experimentally proved, the statement is open to grave doubt. Allotropy has long exerted a peculiar fascination, and though holding good in certain cases, its application to the hardening and tempering of steel is not yet realised. But a stronger statement is made on page 4 of the sixth report.

"The prevalent belief, therefore, of nearly two centuries, which claimed attention for carbon alone, has had to be abandoned."

This statement is made in spite of the fact that the particular use of every ounce of steel commercially produced is determined entirely by its content of carbon. The classical research of Professor Arnold on "The Influence of Carbon on Iron" is sufficient to show that the dominating influence of carbon has not yet been, nor will be abandoned.

Statements of the foregoing character illustrate a growing tendency, in all branches of metallurgical research, to generalise on insufficient experimental evidence. The sooner the pendulum swings back to exhaustive original work the better for science as a whole.

Turning to the work presented in the report recently issued the first striking feature lies in the low mechanical properties of the steels experimented on. The following results obtained from rolled steels are worthy of attention:—

No.	Carbon %	Maximum stress. Tons per sq. in.	Elongation % on 2 ins.	Reduction of area %
1	0·130	30·22	20·0	34·73
2	0·180	31·52	12 5	29·71
3	0·245	33 25	12·7	25·31
4	0·468	30·96	6·25	18·76
5	0·722	49·00	11·72	3·43
6	0·871	58·02	5·47	5·38
7	0·947	53·74	7·03	5·63
8	1·306	56·11	7·03	8·48

No. 4 is very justly described as an abnormal result. The preceding two are equally abnormal, and their elongations are such that no engineer would accept from rolled mild steel. Even steel castings properly made and of similar analysis would yield better results when tested in the cast condition.

A micrographic examination showed that the bars had not been submitted to cold rolling, but the conclusion is reached that they had been rapidly cooled near the critical point, Ar. 1. In the subsequent discussion these extremely poor results were stated to be due to reeling, but this explanation can hardly hold good, for a series of tensile tests on rolled and reeled steels of similar carbon contents have been obtained, showing a range of ductility far in excess of that obtained in the present case.

Whatever the fault the steels were certainly unsuitable for research; the results obtained do not represent the heat treatment of ordinary steel but the "cooking" of originally bad material.

Invention.

Most busy men would rather walk a mile than risk an interview with the average inventor who calls to expatiate upon the merits of some wonderful contrivance he has devised. This frame of mind by no means implies ignorant objection to new and improved things, but is chiefly due to the prevalence of professional inventors—ingenious but misguided people—who are always ready to waste the time of others in trying to persuade them to adopt or to purchase patents usually embodying impracticable or unnecessary ideas. People of this class would invent anything to order, but as they seldom get a chance their efforts run to seed in other directions, much to the prejudice of really meritorious inventions suggested to practical men by the difficulties encountered in the course of daily work.

Apart from great discoveries effecting radical changes in the social and industrial economy of the world, perhaps the most important class of invention is that whose object is to produce by mechanical means articles that otherwise must be produced by manual labour. Inventions of this character form the chief subject of the

recent presidential address of Mr. J. Fletcher Moulton, F.R.S., to the Junior Institution of Engineers. Although not a professional engineer, Mr. Moulton is a distinguished mathematician and scientist, whose experience as a patent-law expert gives him exceptional qualifications for the discussion of the subject to which we refer.

There are several points in his address which well deserve the careful consideration of our readers. As he justly remarks, it would be an idle feat to devise any new method of production that could not effect its purpose better or cheaper or more swiftly than the method which it is intended to supplant, and the machine which accomplishes the task most thoroughly is the one that will ultimately succeed. Therefore, before commencing his design, the inventor has a preliminary task to accomplish, on the correct performance of which his success chiefly depends, and in which his inventive capacity will be tried to the utmost.

The inventor has first to find a series of operations which are more or less equivalent to the series adopted by the handworker, or which give a similar result. Then when a new method of work has been evolved, there remains the task of providing the means for realising it in a practical manner.

It must be remembered, however, that the progress of an invention has by no means come to an end when the machine has been devised. Disregard of this truth is the stumbling-block of most inventors. In the first place, the new machine generally becomes the subject of further invention, the aim of which is to produce better results, by modifications of, or additions to, the mechanism. This brings us to a second type of invention more especially open to the practical man who has had opportunities for observing the operation of the original machine in actual work. Subsidiary inventions of this kind usually consist in the embodiment of mechanical devices better suited for the work which they have to perform, although the essential characteristics of the machine may remain unchanged. This kind of adaptive invention may seem comparatively uninteresting, but it is of immense use; for to increase the output of a machine, or to make an essentially delicate machine fit for heavy work, must extend and may even create its practical usefulness.

It is here, the author remarks, that the lawyer's difficulties are greatest. The benefits of the patent laws being confined to inventions, it often becomes necessary to ask whether a new machine or the modification of an old one involves invention. Mr. Moulton points out that when the essence of a patent is to be found in an improvement upon existing mechanism by the substitution of different but equivalent devices, it is extremely difficult to arrive at a decision, as no definition of the term "invention" has hitherto been formulated, and, in his opinion, no definition of the slightest assistance in such cases will ever be found. Extreme cases are easy of decision, but those occupying an intermediate position can only be decided by personal opinion. For instance, some elements of the device may be altered so as to improve, but not essentially to change its working, and in such a case it is very difficult to say whether the result will be regarded by the law as a new invention. In this country the Courts lean to the practical rather than to the dogmatic side of the question, imposing no rigid test such as that established by the German Patent Office, namely, that a new combination must produce a new result. An appliance that will do the same work better, or in a way different from that previously available, certainly gives to the public a useful choice of means, and in our opinion deserves to be regarded as an invention.

Some good counsel is given in the address to the class whom we may term "restless inventors," who are advised "to bear constantly in mind that the value and the reward of an invention comes when it has been made practically serviceable to mankind, and that the invention itself is but the first and perhaps not the most difficult step in the process." We fully agree with this opinion, but the worst of it is, that when people are once bitten with the mania for inventing things, they never know when to stop, and are rarely

content to work out practically what they have invented. It may be suggested that the practical development of an invention is not the business of the originator, and no doubt there is much truth in this opinion. But the practical remedy is perfectly simple, and is to be found in the co-operation of the inventive genius with a thoroughly practical business man. In joint efforts of the kind we are certainly far behind our competitors in Germany and the United States. In the latter country especially, men possessing the faculty for invention are retained by great industrial firms for the purpose of making inventions, which, if found practicable, are introduced on a commercial basis.

The answer given by Mr. Moulton to the question "In what direction is invention trending?" is well worthy of note. He points out two directions now evidenced in industrial practice. On one hand, the tendency is to divide manufacture up into various operations, each capable of being performed by a special machine, designed solely for that purpose and thus working under the most favourable conditions. He draws attention to the fact that increase in accuracy and workmanship is tending to increase the demand for unskilled labour, as the skill formerly demanded from the workman is now embodied in the machine. He suggests, however, that the growth of production will be so rapid that the total demand for skilled labour may not actually diminish, although relatively to unskilled labour it will grow less and less. Excessively hard and rough forms of manual labour may be done away with, but their place will be supplied mainly by unskilled labour. Another tendency instanced by the author is towards the adoption of machines combining a whole series of successive operations, and so turning out a completely finished article. This development is strongly evidenced in the United States, where the methods of co-operation, to which we have previously referred, bear excellent fruit. Very few inventors have either the time or the capital for working out the details of a complex machine, so that it may be firmly established on a commercial basis with a minimum loss of time. The inventor may spend the best years of his life in trying to perfect some excellent idea without arriving at any adequate result; or, even if he succeeds in his endeavour, the value of the invention may be seriously impaired by altered requirements. In the United States it is generally easy for an inventor to secure the practical support of some wealthy firm for a really meritorious idea, with the effect that it can be produced in practical form within a comparatively brief period. We have an excellent example of this policy in the development of the Curtis turbine, the inventor of which might have wasted twenty or thirty years in the effort to bring it to the state of perfection now attained by the instrumentality of an extensive industrial organisation.

Although dedicated to engineers who are chiefly in the early stage of their professional career, the address delivered by the new President of the Junior Institution of Engineers is one that deserves to be read and studied by all who are actively engaged in industrial pursuits.

Live Steam Feed Heaters.

In a previous article on "Live Steam Feed Heaters," the conclusion was reached that the efficiency of this method of feed heating was due to the fact that the circulation of water in the boiler is improved; that therefore more heat is transferred from the flue plates to the water, and consequently a less proportion of the whole heat generated in the furnace is rejected in the chimney gases.

Some criticisms of this theory have been made, and are dealt with below. The first states that the result of introducing hot feed-water into a boiler instead of cold feed, is to make the temperature within the boiler more uniform, and, as circulation depends upon differences of temperature, the result is, instead of improving the circulation, to make it less rapid.

Now it is quite true that a higher uniform temperature in the boiler would not improve the circulation, if this was

all; but the great objection to cold feed-water is, that, being very often introduced near the surface of the water in the boiler, it, in its downward flow, interferes with the upward motion of the rising stream of hot water and steam bubbles, and in this way hinders circulation.

If the feed is hot when introduced, this hindrance is removed, as, the feed being of the same density and temperature as the surrounding water, it at once joins in the current already set up, and will thus at least not hinder, if it does not actively help circulation.

Again, it has been stated, that for a more rapid exchange of heat to take place between the furnace and the water, it is solely necessary that the difference in temperature between the source of heat and the heating surface should be increased, and that therefore the temperature of the water side of the plate should be lowered.

But the heat transferred to the water in a boiler through the flue-wall, besides depending to some extent on the difference of temperature between the furnace and the water, depends also to a very large extent on the velocity with which the water sweeps over the furnace plates. In fact it is mainly this which settles how much heat shall be abstracted from the inner face of the plate, and consequently what shall be the temperature of the outer face of the plate. It must be remembered that the temperatures at the surface of the furnace plate are not the same as those of the furnace and of the water in the boiler, but are respectively higher and lower than these.

The chief difficulty in the transmission of heat from furnace to water is due, not to the presence of the furnace plate, but to the difficulty of transmission from the furnace gases to the plate, and from the plate to the water. As conduction of heat through water is very slow, it follows that a vigorous circulation, which sweeps off from the furnace plate the film of highly-heated water and of steam bubbles, allowing cooler water to come in turn in contact with the plate, will directly lead to an increased transfer of heat from furnace to water.

Increased circulation has considerably more effect than increased difference of temperature. It has been also contended that, whereas with cold feed-water part of the flue surface is occupied in raising the temperature of the water, when hot-feed is used the whole of the flue surface is performing the act of evaporation, during which process the transfer of heat is said to be more rapid.

But as generally the feed inlet is at some distance from the flue, the cold-feed will be heated by the surrounding water to almost evaporation temperature before coming in contact with the flues. Also, if the transfer of heat during the process of evaporation is more rapid, it is simply because of an increased rapidity of circulation, as even during evaporation the heat has still to be transferred by contact from the flue surface to the adjoining film of water, so that as before the transference is between a heated solid body and a fluid.

Another contention was, that the increased efficiency is partly due to the fact that steam heating of feed-water is a rapid process, the system thus making for increased activity as a process—also it is stated that it is clear that the system is wholly beneficial in any case, for, if the water does not require the heat of the steam, it will not take it up.

But this latter statement overlooks the fact that the process of live-steam heating—being, as usually carried out, essentially non-reversible—is wasteful, if considered from the standpoint of thermodynamics; just as the drop in steam pressure between the cylinders of a compound steam engine is non-reversible, and therefore is bad thermodynamically. This being so, it is certainly not at all clear, without looking carefully into the various physical or mechanical actions which take place inside a boiler, that the system of live steam feed heating should lead to increased economy. At first glance, it would appear most unlikely that it should be so in fact.

It seems clear then, that this increased efficiency is directly due to the increased circulation, which takes place when hot feed, as opposed to cold feed, is introduced into a boiler.

The increased efficiency of the two-, or three-stage feed heater, over the single-stage heater is due entirely to the fact that the process becomes more nearly a reversible one as we increase the number of stages. If we could imagine the number of stages to be made very great, while the rise in temperature of the feed between any two stages is very small, we should approximate very nearly to the perfect — thermodynamically — feed heater.

LETTERS TO THE EDITOR.

Editor, ENGINEERING REVIEW,
104, High Holborn, W.C.,
London, England.

DEAR SIR,

The very courteous review of my "Thermodynamics of Heat-engines," which appeared in your issue of October last, has just reached my eye. Will you allow me to answer a few questions which are raised, more or less succinctly, therein?

(1) The MS. of my "Thermodynamics" was sent to the publishers in July, 1902, some five months before Mr. Swinburne opened the discussion referred to in the review.

(2) The statement of general principles and the definition of entropy given in my book were due neither to carelessness nor to ignorance of the orthodox doctrines in those directions.

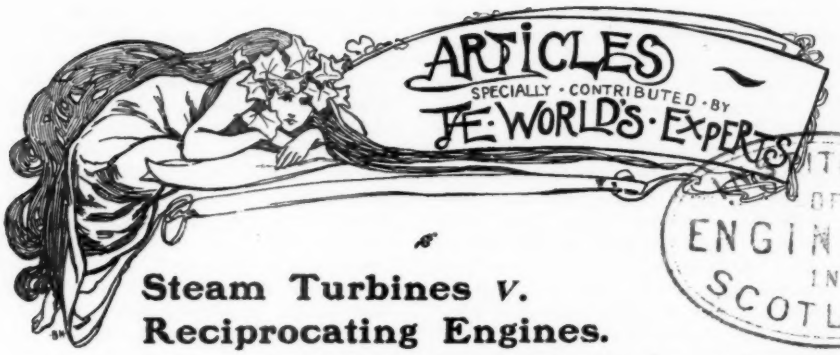
(3) The general mechanical philosophy outlined therein is not, therefore, to be indicted under the terms in which Mr. Swinburne and the reviewer sweepingly condemn the text-books, that of looseness. It is the result, on the other hand, of the hopeless inconsistency and blindness of the whole orthodox school of thermodynamics, which may be defined as falling between Professors Clausius and Willard Gibbs. Dissatisfaction with the orthodox definition of the Second Law, and with the superstitious awe with which entropy is regarded as a "ghostly" quantity, has been widespread and well sustained. Even Professor Max Planck, staunch upholder of the Clausius-Gibbs-Duhem school as he is, writes in *The Electrician* for March 6th, 1903, p. 821, as follows:—"What I do emphatically deny, and always have combated, is the proposition adduced by Mr. Heaviside of the universal dissipation of energy." In the field of astronomical science the whole hypothesis of the nebular evolution of stellar systems, in its complete statement, stands in refutation of this same doctrine as a universal law, and the battle is now being fought out along exactly the same lines in astronomical philosophy as it is in thermodynamic.

What I crave, therefore, is recognition as a belligerent. The present situation is no bread riot of the densely ignorant, nor a guerilla rebellion of the lazy and dissatisfied. It is an invasion, made upon principle, into the hitherto peaceful stronghold of the conservative and self-satisfied accepted authorities. It re-defines the Second Law so as to give to the universe a more natural aspect than that of a clock which some Primordial Cause wound up ages ago, and which has since been engaged in running down; and which, therefore, can be wound up again only by some equally supernatural catastrophe. It takes entropy out of the control of the spiritualists, and gives to it the same commonplace, knock-down force of character as that possessed by a hammer head. It takes up arms in the same cause—that of the natural, the continuous and the stable *versus* the catastrophic, in the energetic analysis of evolutionary processes which Lyell fought out years ago in their geological, and Lamarck and Darwin in their biological, aspects.

If I should add that the philosophy of scientific sociology is now undergoing exactly the same revolution, substituting natural forces for the supernatural in the explanation of all social phenomena, and replacing the catastrophic confusion of past human chronology with a continuous and stable evolutionary philosophy in the human history now about to be written, the breadth of aspect of this present controversy would be completely stated. For the sciences of astronomy, mechanics, thermodynamics, physics, chemistry, biology, and sociology are now too closely interwoven for any broad principle or belief to be taken up in any one of them without careful scrutiny as to what conclusions it must enforce in all of the others.

Yours truly,
SIDNEY A. REEVE.

Worcester, Mass.



INSTITUTION OF ENGINEERS IN SCOTLAND.

Steam Turbines *v.* Reciprocating Engines.

By J. H. BARKER, M.Inst.C.E., M.I.E.E.

Many things in the past two years have brought the subject of Steam Turbines *v.* Reciprocating Steam Engines prominently to the front, but more than any mentioned below none came as a greater surprise, or spoke more for the merits of the newer motor, than the statement by the chairman of a firm of leading engine-builders in his speech at the general meeting, that they were about to undertake the manufacture of steam turbines. The other items are the placing of contracts for large turbine installations by the Metropolitan District and Metropolitan Railway Companies, the Yorkshire and Lancashire Power Companies, and nearer to the home of the turbine, the Newcastle-on-Tyne Electric Supply Company ordered four of a total output of 11,000 kilowatts. Corporations have not hesitated to employ turbines; Manchester, for instance, has two of 1,800 kilowatts each, Sheffield two of 1,500 kilowatts, and Liverpool and Brighton have ordered others. Lastly, the electrical press has opened its columns to an extensive correspondence originating in the reading of a paper by a user of turbines and continued by a leading engine-builder, which has done more to advertise the turbine by eliciting its merits than could possibly have been done by its manufacturers unaided.

The writer of this article has had exceptional opportunities of observing the progress and merits of the turbine. After being trained for six years in factories building reciprocating engines only, and having had experience as a sea-going engineer, he was placed in charge of one of the early Parsons turbines, of 16-kilowatts output, running at 9,000 revolutions per minute. Furthermore, he was engineer to a public supply station for nearly eight years, employing over 1,000 kilowatts of turbines, and for three has been engaged in their manufacture and design.

The champions of reciprocating engines credit their opponents with holding the idea that turbines are superior to every other steam motor. Let it be stated, however, at the outset, that in this article no such claim is promulgated, as for the last year the writer has devoted a large amount of his time to the development of a high-speed double acting engine with considerable success, and had the satisfaction (or otherwise) of having under construction a greater number of reciprocating engines than turbines.

The reciprocating engine has by no means come to the end of its life, and its almost universal application will for very many years continue to provide engine-builders with work. It will start against overload, will reverse, and run as economically one way as another, and at varying speeds with corresponding consumption of steam. These three advantages open a field of usefulness that the turbine can

never unaided fulfil, especially as regards steam locomotion, rolling mill driving, and marine-work for tramp steamers.

In a general way engineers are not recommended to employ turbines of lower output than 150 kilowatts; nor at all, except for very large sizes, unless a higher vacuum than 25 ins. of mercury with the barometer at 30 ins. is available, not for alternators of a lower periodicity than 40 per sec., unless of a larger power than 500 kw.; lastly, it is still considered an open question as to whether turbines should be used attached to continuous-current dynamos. As regards the latter point, the number constructed would rather appear to provide an answer in the affirmative, but when it is taken into consideration that carbon brushes are as yet not admissible (the high rate of speed almost sets them on fire) it is easy to see how greatly the electrical designers are handicapped in this matter.

It has been said that the difficulties of dynamo design increase in the ratio of the square of the periodicity in the conductors; a very ordinary figure for the multipolar is 12, whilst the lowest for a turbo dynamo is 40, with even two poles.

In spite of these obvious disadvantages, many more continuous-current machines have been made than alternators, and if attendants would only give a little extra care to the commutator and trimming of brushes, the disadvantages of the dynamo would be more than compensated for by the use of a turbine.

This is conceding much to the reciprocating engine, and appears to leave little scope to the turbine. Before considering the latter under the most favourable conditions of working, it is of interest to see what can be done in adverse circumstances. A reference may as well be made at the outset to a case in which the merits of turbines were more nearly compared with reciprocating engines for a particular purpose than ever before or since. The pioneer electric supply companies in London had many difficulties to face—costly land, smoke nuisance, costly water and coal—and to all these were added the claims for an injunction from angry neighbours on the ground of the transmission of vibration to their houses from the adjoining engine-room. So serious had this become that the Metropolitan Electric Supply Company, after expending enormous sums on increasing foundations, were ordered by the Court of Chancery to cease running on a certain day unless the disturbance could be stopped. Herewith came the opportunity for turbines. The whole of the reciprocating plant was removed, and turbines installed, with the result that the plaintiffs were completely satisfied, and the injunction was not enforced. This was undoubtedly a victory, and, considering that they are working non-condensing, it is a double triumph. Other instances of the adoption of turbines in order to avoid vibration are at the Hotel Cecil, where not only are the units of small size—75 kilowatts—but they also exhaust to the atmosphere. In spite of this cost of supplying electricity to the hotel is considerably less than if it were purchased from the public supply authority. The new Savoy is apparently following the example of the Cecil, for tenders have been recently invited for turbines to supply these premises when complete.

The advantages possessed by the turbine, when compared with the reciprocating engine, may be presented under the following heads:—

1. Small space occupied.
2. Low first cost, upkeep, and attendance.
3. Lighter foundations, and no holding down.
4. Governing with speedier gear and efficient lubrication.
5. Initial steam economy maintained.
6. No cylinder lubrication, and exhaust steam free from oil.
7. Economy in steam consumption.

Of these headings the turbine can claim to be superior as regards Nos. 1, 2, 3, and 6; of the other three it is no exaggeration to say that it can hold its own. To consider these in detail.

1. *Space occupied.*—Reciprocating engines of the high-speed type have been so improved of late years, that in the matter of floor space they run the turbines close until the very large sizes are reached.

The figures given in a table of sizes issued by the Brush Electrical Engineering Co. are somewhat anomalous, as they can be made to prove either case when comparing turbines of the Parsons type, and double-acting reciprocating engines of an improved pattern up to 500-kw. output. But it must be remembered that a very few turbine patterns cover a large number of sizes, whereas engine patterns are much more numerous; for instance, the length of a 200-kw. turbine and one of 400 kw. are identical, and the same pattern is used from 400 kw. to 800-kw. sizes, and, again, from 800 kw. to 1,500 kw. Unless there is some special reason for economising space, an intermediate size is never made. Reciprocating engines, on the contrary, can only be varied within very small limits, and new patterns are required with every increase of 20 per cent. up to 40 per cent. of power.

It is only fair, however, to say that the turbine has a somewhat inordinate length, and for this reason has more than once been unable to take its place in a station already erected. In the case of the Curtis turbine, however, which is now being built in large numbers, this disadvantage will be overcome.

The curves given in Fig. 1 have been plotted on the basis of the figures given in the Brush Company's list and show the areas and heights of each type. It will be noted that the floor space occupied is very much the same for both types up to 500 kilowatts, but from that point the turbine falls away rapidly.

The superiority of the turbine as regards height is maintained throughout, and avoids the use of platforms, except in the larger sizes, and even then only a first landing, instead of the two, or even three, required for reciprocating engines of the same output. Whilst floor space is undoubtedly the chief consideration, a low building is much less costly to construct than a high one, and a turbine station could quite easily be built over the boiler-room; or, to take the case of the Bristol Tramway Station, the boilers could have been placed over the engines at a very

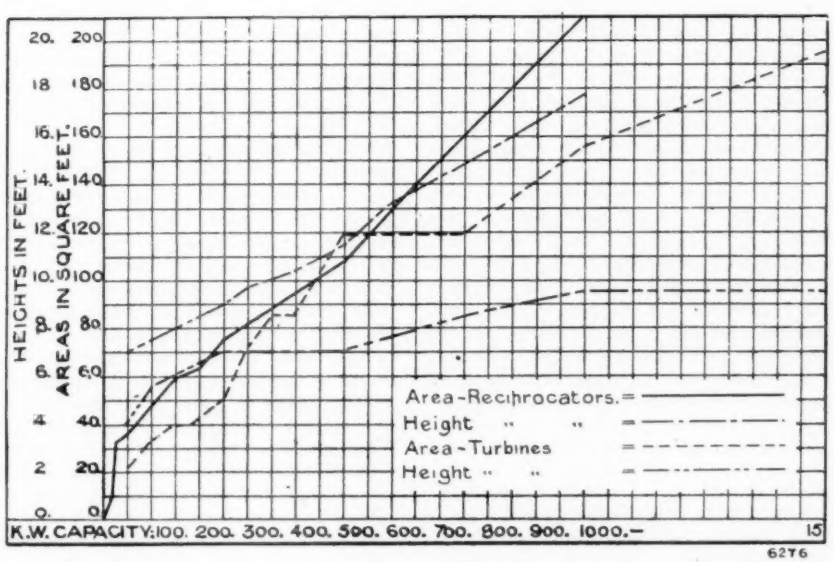


FIG. 1.—CURVES PLOTTED IN RESPECT TO HEIGHT AND AREAS, AND KILOWATT CAPACITY OF RECIPROCATING ENGINES AND TURBINES.

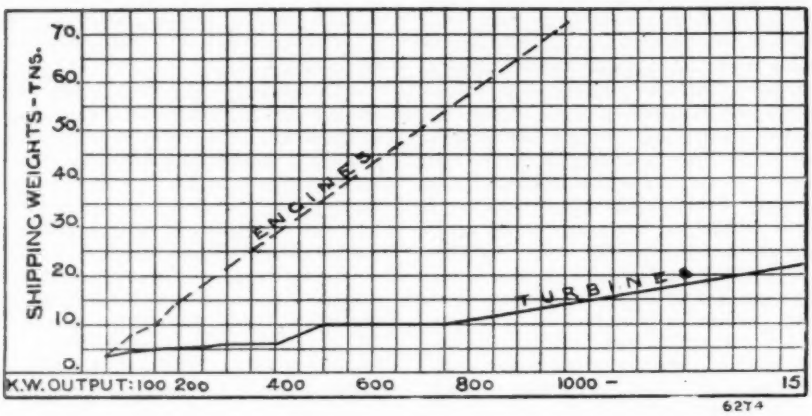


FIG. 2.—RECIPROCATING ENGINES AND TURBINES COMPARED AS REGARDS THE RELATION OF SHIPPING WEIGHT TO OUTPUT.

much less cost than must have actually been incurred.

2. *Low First Cost.*—The first cost of a turbine is difficult to compare with that of the reciprocating engine, but it is probable that in a shop suitably equipped for the manufacture of each type a turbine of 250-kilowatt capacity would cost quite as much as a reciprocating engine. Below this size the cost would be more, and above less, until 5,000 kilowatts is reached, when the price would be very considerably less. A glance at the weights as compared with the output will be instructive. This comparison is made in the curves (shown in Fig. 2), in which the output is plotted for abscissæ, and shipping weights for ordinates. As the proportion of cast-iron and steel is much about the same in both cases, it affords an idea of what the cost should be. The turbine is taunted with forming so small a part of the world's total of prime movers; but it must be remembered that the reciprocating engine has a record of over a century and become standardised—it might almost be said, stereotyped—whilst the turbine has but twenty years' record. When the latter has had more time to consolidate, and its makers can build in batches of twenty as a minimum, the cost must be reduced to a very large degree.

The cost of upkeep affords a question about which a very great deal has been written and as little known by the general engineering world. It is stated that blades must wear for the same reason, presumably, that steam stop-valves wear or are cut by the passage of steam, but the analogy is not by any means perfect. Is it supposed that the old Newcomen engines cut their valves in like manner? Even so the velocities of steam in a turbine over any of the blades are much less than those due to the pressures of the earliest examples of steam engines. A little thought and calculation would prevent engineers of considerable eminence continuing to cherish this idea. The older type of radial-flow turbine could wear its blades, as there was adjustment longitudinally in the direction of the blade length; but, even so, the cause of wear reduced the clearance, and things were for a long time in *statu quo*. The present turbines may wear from two causes; one is imperfect erection. If the cylinder is not allowed to expand lengthwise flexure of the barrel must take place, which will cause the blades to touch either on the top or bottom. In the same way a locomotive boiler, if held rigidly, will leak at the seams and rivets and heat up at the journals; and yet no one dreams of dis-

continuing this type for so obvious an error. The second cause is through wear of the bearings, which, if allowed to go on, would certainly cause reduction of blade-tips, but how little shafts sink in their bearings is pointed out further on, and is quite a negligible quantity.

A perusal of the costs of a station using turbines over a series of years will demonstrate that the steam consumption does not increase as alleged. Cambridge has in every year but one reduced its coal bill per unit sold, the exception being due to the coal boom in 1899, when prices advanced some 50 per cent. Even then, the figure was equal to its predecessor. In this station, which has now been running eleven years, there have been only three repairs to blades; one in 1893, the other two in 1897. In the first case, one disc out of seven required re-blading after a runaway, the engine being unprovided with an emergency governor; in the second case, a single row on a day-load plant driving its own jet-condenser air-pump; and the third on a day-load plant, a hot bearing caused wear, and 20 mils. were worn off as many rows of blades. Out of seven machines only three have needed blade repairs in eleven years, all of which were due to preventible causes. Of course, if bearings are allowed to wear down, trouble will ensue; but then with a reciprocating engine, if bearings and big ends are not taken up, the whole engine will collapse, or at least the covers be knocked off. The wear on the only true working rubbing parts, viz., the two main bearings, provided they are well looked after, is less than 1 mil. per annum, due to the friction set up by the rotation of a perfectly-balanced mass without alternation of pressure or hammering, as on engine-bearings or connecting-rods.

The upkeep of a reciprocating engine is not a matter that causes any anxiety to its attendants. It must, however, be represented to a certain degree by the number of wearing parts, and that it has not become a serious cost in the electric lighting world is possibly due to the short hours all plants run, and to the rapid advance of undertakings.

Experience has shown that all types of engines have been superseded long before the time that they needed any serious repair.

Small Attendance.—Under heading two, the third item is small attendance. What is comprised in attendance rather needs definition; for the purposes of comparison it should only include such men as are occupied on the engines for the purpose of driving exclusively, apart from switchboard or auxiliary machinery. For large-sized engines, say over 1,000-kilowatt capacity, there must be at least two men employed, one on the ground level and one on the upper platform. For the turbines, one man can, with care, look after at least two of the largest turbines ever built; every bearing is accessible from the ground floor, and all he need do is to watch the tachometer, oil-pressure gauge, and feel the bearings. It is difficult to imagine anything more simple.

3. *Lighter Foundations and No Holding Down Bolts.*—The weights shown on Fig. 2 give some idea of the amount of foundation required to support a turbine compared with its competitor; and, if a block of sufficient rigidity is assured, that will subside without breakage or flexure, no precaution need be taken to prevent the transmission of vibration or to maintain either level or perpendicular. In the test house of a turbine factory the machines are mounted on cross timbers of about 12 ins. by 12 ins., without any holding down bolts, and they run quite as well as on their permanent foundations.

4. *Governing and Lubricating.*—Without in any way disparaging the excellent results obtained by reciprocating engines in the way of governing, the method perfected by Mr. Parsons of admitting steam intermittently by means of a steam relay can claim to be equal to anything attained by other motors; in addition to this, the perfect turning of the turbine adds very much to its success. The best testimonials the writer has seen of turbine governing was a voltage card from the city of Elberfeld, where there are Sulzer engines and two Parsons turbines. The engines are fitted with both alternators and direct-current dynamos, the latter for traction work; the turbines with alter-

nators only. The pressure was taken from the alternator busbars. To maintain the overhead railway at work a Sulzer set ran all day, and the turbines were put in for lighting. The voltage showed the usual broad irregular line of a width equal to the amplitude of variation four or five volts; as soon as the turbine was put in it became, during the whole of its run, almost a straight line of the width of the pen.

Lubrication is very simple; there are only two bearings and a thrust on the turbines compared with six on a three-crank engine, as well as connecting-rods, guides, and valve-rods. The forced lubrication of a reciprocating engine is certainly a model of ingenuity, and the cleaning of the many and tortuous passages a matter of considerable time and trouble.

5. *Initial Steam and Economy maintained.*—To demonstrate the maintenance of the initial economy of a steam turbine, Messrs. Parsons & Co. obtained leave to make use of a 500-kilowatt steam turbine at the Cambridge Electricity Works, and appointed Professor Ewing to carry out the tests; the results obtained were referred to in the technical press at the time. It was found impossible to make the trials in every respect identical with those at the makers' works when new. Firstly, to obtain steam pressure at 140 lbs. it was necessary to use the two boilers furthest away from the turbine, and as water in the steam has no effect on a turbine in damaging its parts, no complete system of separators were in use compared with those supplied in a test-house; the steam was, therefore, by no means saturated. At the manufacturers' works it was impossible to make the trials with the turbine driving its own pumps (air and circulating), and an allowance of 5 per cent. was made for this. Two tables, *A* and *B*, set out the figures obtained in each case, and the results are plotted in Fig. 3. In so doing, however, a correction has been made of 1 per cent. for the extra 9 lbs. of steam pressure, 5 per cent. at 500-kilowatt output for driving pumps, and 2 per cent. for extra vacuum.

Table A.

TRIALS OF 500-KILOWATT TURBINE AT MAKERS' WORKS. OCTOBER 27, 1899.

No. of Trial.	1.	2.	3.
Output in kilowatts	526·4	256·1	124·0
Volts at terminals	2,015·0	2,115·0	2,015·0
Revolutions per minute	2,750·0	2,750·0	2,700·0
Air-pump discharge lbs. per hour	12,675·0	7,029·0	4,180·0
Air-pump discharge per kilowatt hour	24·1	27·5	33·7
Pressure at stop-valve	139·0	145·0	140·0
Vacuum in turbine	24·5	26·6	27·6

Table B.

TRIAL OF 500-KILOWATT TURBINE AT CAMBRIDGE. JANUARY 9, 1901.

No. of Trial.	1.	2.	3.	4.	5.
Output in kilowatts	518·0	586·0	273·5	160·5	—
Volts at terminals	2,100·0	2,150·0	2,250·0	2,290·0	2,280·0
Revolutions per minute	2,670·0	2,740·0	2,630·0	2,590·0	2,580·0
Air-pump discharge lbs. per hour	12,970·0	14,320·0	7,730·0	5,320·0	1,850·0
Air-pump discharge per kilowatt hour	25·0	24·4	28·3	33·1	—
Pressure at stop-valve lbs. per sq. in.	148·0	145·0	151·0	151·0	121·0
Vacuum in turbine cylinder	25·7	25·4	27·2	27·8	28·1

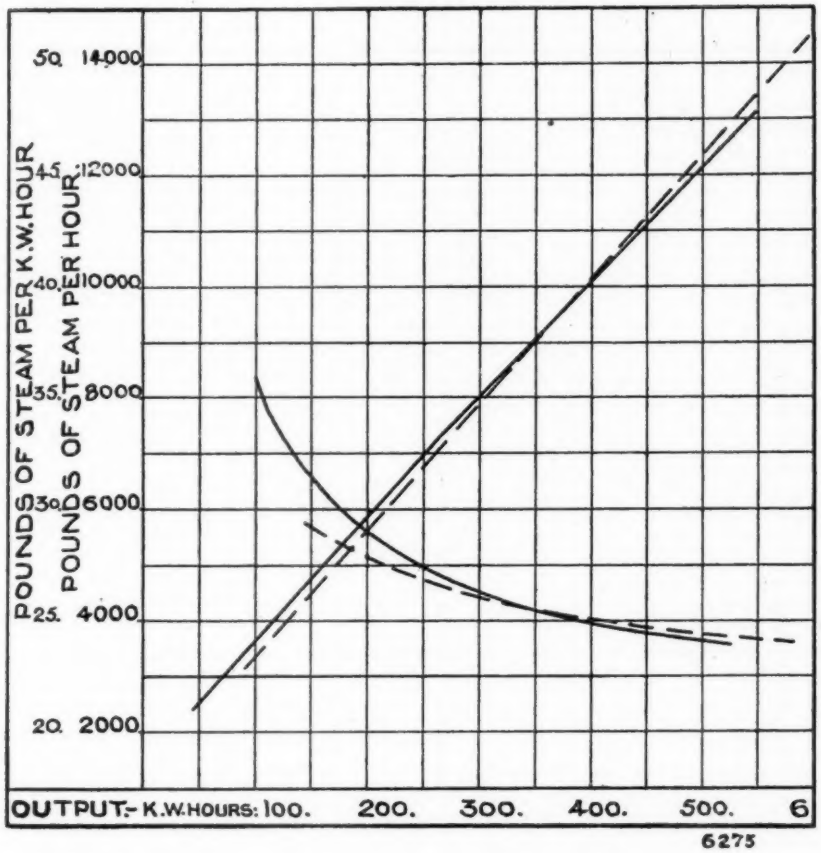


FIG. 3.—TESTS OF 500-KILOWATT TURBINE AT CAMBRIDGE AND MAKER'S WORKS COMPARED.

A second trial for maintained efficiency was made by Mr. George Wilkinson, M.I.E.E., of Harrogate, on a 300-kilowatt alternator, and the results were given in a paper read at Leeds before the Local Section of the Inst.E.E., these also showing that his turbine at Harrogate had maintained its efficiency.

On the reciprocating side trials are published in the "Mins. Proc. Ins. C.E.," Vol. CLI., p. 208, of a high-speed engine after 5½ years' service, which show some very excellent results, and in this case the tests were made under absolutely similar conditions, excepting for vacuum, which was at full load 2 ins. better, and according to the maker this is equal to 3 per cent. Table C gives these figures, and Fig. 4 the same plotted with correction, and reduced to kilowatts on a basis of b.h.p. to e.h.p., 93 per cent. The surprise is not at there being wear (for however well lubricated two surfaces rubbing together may be, there must be some wear), but that it is so truly microscopic.

Personally the writer would not from

Table C.

TRIAL OF COMPOUND ENGINE 12" + 20" × 9½" NEW. JUNE, 1896.

—	Full Load.	¾ Load.	½ Load.	¼ Load.
Steam Temperature F.	377·5°	268·6°	372·0°	361·0°
Vacuum, inches	25·75"	26·5"	26·5"	26·5"
Revolutions per minute	364·0	360·0	359·0	359·0
B.H.P.	218·4	162·0	107·7	53·8
I.H.P	245·5	184·5	126·9	65·63
Water per B.H. hour	19·4	19·9	21·3	22·9
Water per I.H. hour	17·3	17·48	18·08	18·7
Efficiency per cent.	89·0	87·7	84·8	82·0
Steam Fressure	154·0	154·0	142·0	147·0

TRIAL OF SAME ENGINE 5½ YEARS AFTER. APRIL, 1902.

—	Full Load.	¾ Load.	½ Load.	¼ Load.
Steam Temperature F.	372·5°	377·0°	377·0°	
Vacuum, inches	27·8"	27·8"	27·8"	
Revolutions per minute	360·0	360·0	360·0	
B.H.P.	218·0	162·0	108·0	
I.H.P.	231·6	173·5	117·0	
Water per B.H. hour	19·3	19·3	20·4	
Water per I.H. hour	18·15	18·02	18·8	
Efficiency per cent.	94·0	93·3	92·2	
Steam Pressure	151·0	137·5	150·0	

the figures like to say there is any real superiority in either type of engine in this respect.

6. *No Cylinder Lubrication.*—This is a matter about which there can be no dispute; a reciprocating engine must be lubricated, and the quantity of oil observed in the weighing-tank of a reciprocating engine test-house shows the value put on it for attaining their results. To make a test comparable to a turbine this oil should be converted to its equivalent money-value in steam, and added thereto. It is well known by the donkey-man, the practical increased efficiency of his charges by a liberal allowance of oil, and the same applies in a lesser degree to engines of a larger size. Not only is the cost of oil a serious item, but the effect on the boilers is disastrous. Many means are employed to nullify this, with more or less success, but that it is a serious trouble is testified by some engineers preferring to discharge their surface-condensed water into the river or sewer to employing it for boiler feed.

In one large station using turbines and reciprocating engines, the use of the former means 5 per cent. in the coal bill for oil alone.

Condensed water from steam turbines is absolutely pure, and may be used for drinking purposes. As boiler feed it is ideal; the make-up required in most towns is just sufficient to give the requisite amount of hardness to prevent corrosion of plates.

7. *Economy in Steam Consumption.*—This all-important question is treated last, and the more it is examined, the more one concludes that figures can be made to prove anything. In the recent correspondence extracts from station reports using reciprocating engines were shown to be superior in coal consumption to turbines; but when the stations using turbines non-

condensing—a purpose for which at present they are not suited—were eliminated, the result was the other way. Valuable as the published figures in the several journals are, it is very doubtful if any real information can be gathered to prove the relative economy of the rival systems; for, although coal is the first essential for electric power in this country, it is so hopelessly connected with quality, carriage rate, boilers, and feed-heaters, before its heat reaches the engine; and after passing the prime mover the confusion is even worse in dynamo efficiency, load factor distribution, efficiency, and metering. Above all, there comes the personal element of the engineer in charge, which is capable of making or marring the reputation of any station; and can almost without consciousness effect a saving or make a loss greater with either reciprocating or turbines than the differences between the figures advocated by the champions of both.

After all, it would appear that the fairest way of judging what either engine can do is to take manufacturers' own figures. If one contractor is honest and fair, it is surely reasonable to suppose his rival is quite as honest; if dishonest it is

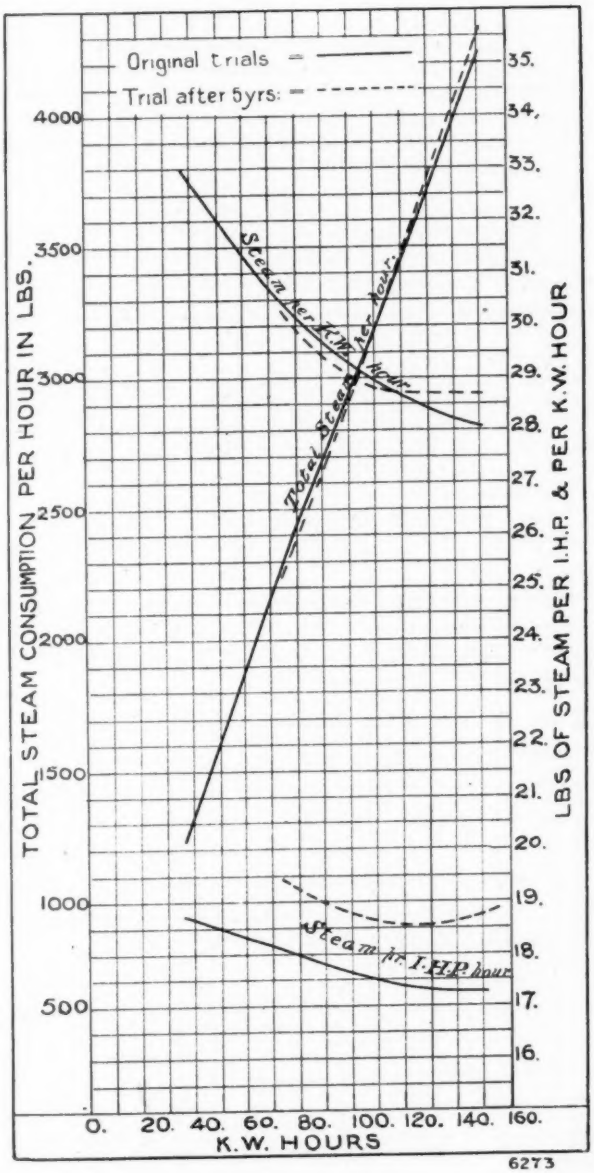


FIG. 4.—RESULTS OF TRIALS AFTER 5½ YEARS' SERVICE OF A HIGH-SPEED RECIPROCATING ENGINE.

Table D.

TRIAL OF TURBO-ALTERNATOR AND RECIPROCATING ENGINE.

Newcastle-on-Tyne Electric Supply Company, Wallsend.

—	TURBO-ALTERNATOR					Wallsend Slipway Engine.
Steam Pressure at Valve ...	196·0	197·0	196·0	199·0	200·0	192·0
Superheat F.	76·0	84·0	76·0	77·0	68·0	90·5
Vacuum. inches	27·4	27·35	27·95	28·35	28·45	25·6
Revolutions per minute... ...	1,200·0	1,200·0	1,200 0	1,200·0	1,200 0	102·3
K.W. output	1,442·0	1,015·5	714·0	360·5	—	609·0
Total Steam per hour	25·962	20·124	15·288	9·114	2,948·0	10,717
Steam per K.W. hour	18·0	19·8	21·4	25·2	—	17·6

impossible to long maintain his reputation, and consulting engineers are surely sufficiently well-trained to know what an engine can do or ought to do, and wide enough awake not to be imposed upon.

The largest turbines in the country are at present running in the station of the Newcastle-on-Tyne Electric Supply Company at Wallsend. There are two of them; the first was designed for 1,500 kilowatts, but with a new alternator has proved itself capable of running at 2,000-kilowatt output. In the same station is a reciprocating engine of only 750-kilowatt output, built by the Wallsend Slipway Company to the design of Mr. Laing, which, in its

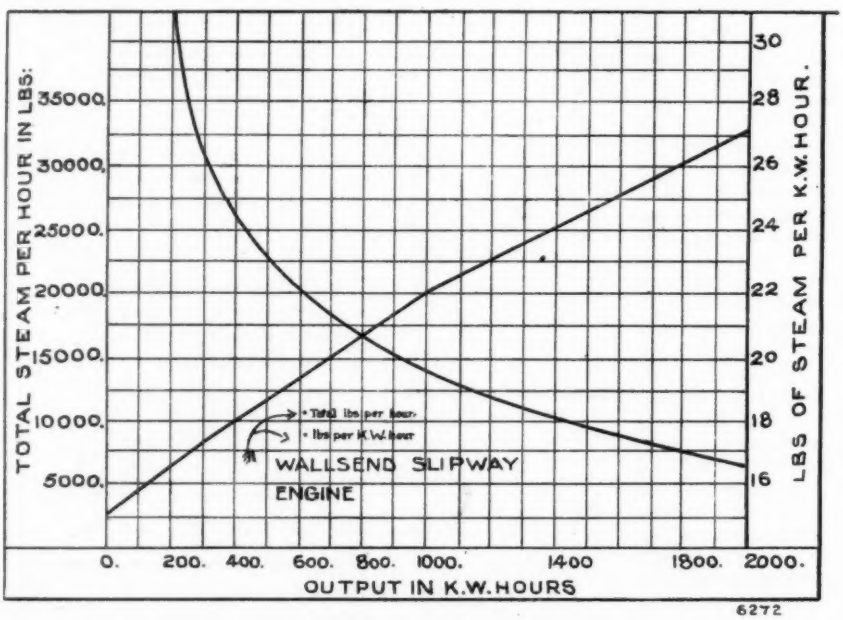


FIG. 5.—TESTS OF A TURBO-ALTERNATOR AND WALLSEND SLIPWAY RECIPROCATING ENGINE.

day, was perhaps the most economical engine in this country under equal conditions. Figures of the test of this have been published several times, and the following are taken from the "Minutes of the Proceedings of the Institute of Civil Engineers," vol. cli., and reproduced in Table *D*. The first of the turbines was also tested, and gave slightly worse results, as given in the same table. If, however, the oil consumed in lubricating cylinders is included, the results are practically equal. The Willans line is more nearly straight than in the reciprocating engine. Up to the full extent of its load, the economy continues to increase so long as full revolutions are maintained, and steam only admitted at the first row of blades. If the Wallsend plant had been tried at 2,000 kilowatts, according to the diagram the consumption should be 16½ lbs. per kilowatt.

The full load of a reciprocating engine is more often than not obtained by a later cut-off in the h.-p. cylinder than can be expanded in the range of the engine, and corresponds to the bye-pass on a turbine, whereby high-pressure steam is admitted at a point nearer the exhaust than by the governor.

In practice, the reciprocating engine scores in the matter of overload. No plant can always run at its maximum load, and therefore engineers specify that their plant shall be capable of sustaining what is termed overload without hand adjustment of governor and valves. To meet this, turbines have to be designed to include the overload and their maximum economy is at the same point. A bye-pass worked by hand is fitted to most turbines, which enables them to perform some 50 per cent. extra work, and recently the Westinghouse Company have applied for a patent for working this from the main governor, which, if successful, will place the two competitors on an equal basis.

The best turbine results up to date have been attained by Messrs. Brown, Boveri, of Baden, Switzerland, where the phenomenal figure of 15·75 lbs. of steam per kilowatt was reached, which has only been equalled by a Sulzer slow-speed of large power and high superheat.

Conclusion.

From the foregoing review of the state of engine-building to-day, it is pretty evident that reciprocating engines will for a very long time have a large demand for powers up to say 1,000 h.p., the smaller the size below this the more tenaciously are they likely to retain their position, but above such a power the trend of opinion is more and more towards turbines, and although reciprocating engines have done excellent service, for high powers their days are numbered.

Utilising the Exhaust of Intermittently-Working Engines.

By J. WALTER PEARSE, M.Soc.Ing.Civils de France.

OWING to the conditions of their working, intermittent engines, such as those used for winding in mines and driving rolling-mills, have hitherto been almost entirely deprived of the advantages secured, in those working continuously, by condensation, multiple expansion, and superheating. The result is that immense quantities of exhaust steam are discharged into the atmosphere with the only effect of increasing the coal bill. Investigations have, indeed, shown that duplex non-condensing engines for winding mine cages consume from 40 to 45 kgs. (mean, 94 lbs.) of steam per h.p. per hour in useful load; and, if it be admitted that 20 per cent. of this steam is condensed in the pipes and cylinders, the net weight of steam at atmospheric pressure lost per effective h.p. per hour is from 32 to 36 kgs. (mean, 75 lbs.), or from 4 to 5 tons, for a winding-engine of medium power. The waste is even more marked in the case of rolling-mills, because they are generally run both night and day; and a reversing roll-train engine consumes, as a rule, nearly 20 tons of steam per hour.

Prof. Rateau, of the Paris School of Mines, obtains perfect utilisation of this waste by means of his steam accumulator-regenerator and a low-pressure steam turbine, coupled directly with dynamos, fans, or centrifugal pumps; thus obtaining a vast surplus of power with a very small outlay for plant, while his method may also be employed with advantage when the existing engines are already provided with condensers or other means for saving steam. The principle of the method consists in directly utilising the exhaust of low-pressure condensing engines, preferably steam turbines; and, as this exhaust is discharged intermittently at about atmospheric pressure, it must be rendered practically constant before being admitted into the low-pressure engine. The steam turbine is preferred on account of its utilising the motive power of low-pressure steam under the best possible conditions; whereas, for the same purpose, reciprocating engines would be large and costly, and their efficiency low. In the Rateau system, means are provided for rendering the primary and the secondary motors perfectly independent, so that each can work at a given pressure without exerting any influence on the working of the other; and the condenser should naturally afford the most perfect vacuum possible.

Accumulator-Regenerator.

The steam accumulator, which is a chamber filled with substances that equalise the heat, stores up the steam exhausted from the primary engine; and this steam is condensed when it arrives in considerable quantities (the pressure and therefore the temperature increasing in the accumulator), but re-evaporates on the exhaust ceasing or diminishing. The constant drawing action of the steam turbine then lowers the pressure, which causes the re-evaporation, owing to the heat stored up in the substances contained in the chamber during the period of abundant exhaust. In practice, the variations of temperature can easily be reduced to a value of from 3 to 6 Centigrade degs. ($5\frac{1}{2}$ to 11 Fahr. degs.), corresponding with variations in pressure of 0·15 to 0·25 kilogramme per square centimetre (2 to $3\frac{1}{2}$ lbs. per sq. in.). The limits of variation may, moreover, be determined by the choice and weight of the substances for storing up heat, and by regulating the accumulator stop-valve. The accumulator-regenerator may assume the three following forms according to the storage substances selected:—

Cast-iron and Water Accumulator.—Fig. 1 shows a vertical section, with part enlarged plan, of an accumulator consisting of one or more cylindrical chambers of plate iron, recalling the hot-air regenerative stoves of blast-furnaces. It is, however, fitted with a series of shallow pans, each of which is divided into three segments, for holding water. The exhaust steam from the primary engine enters at the point *D*, and is distributed over the pans by the central passage *F*, part of the steam passing directly along the inside of the chamber, and then by the outlet pipe *E* to the turbine, while another portion is condensed during the periods of abundant discharge from the primary engines, to be re-evaporated during the intermediate periods.

Scrap-iron Accumulator.—Fig. 2 shows an actual accumulator-regenerator, for 600 h.p., made of an old cylindrical boiler and water-tube, filled with 55 tons of old rails. In this case the advantage of water, the regenerative action of which is added to that of the metallic mass, is sacrificed to the low first cost when there is a stock of old rails on hand. The intermittent steam supply, entering by the pipe *D*, is equalised in the accumulator, and led to the turbine by pipe *E*, a man-hole being provided for introducing the rails into the boiler shell.

Water Accumulator.—While costing nothing, as a rule, water has a high calorific capacity; but it is also a very bad conductor of heat, so that to serve as a steam accumulator-regenerator it must either be spread out in thin sheets, as in the first form of accumulator described, or be made to circulate actively, in order to constantly bring the steam into contact with fresh particles. This is the method adopted by Prof. Rateau, and Fig. 3 shows his arrangement of a water accumulator which is by far the least expensive of the three forms at disposal. It is constituted by a horizontal cylindrical boiler, inside which are four (as shown) or more large horizontal pipes *A* of elliptical section, extending from one end to the other, and leaving between them vertical up-takes *B*. The steam from the primary engine led into these elliptical pipes, which are placed

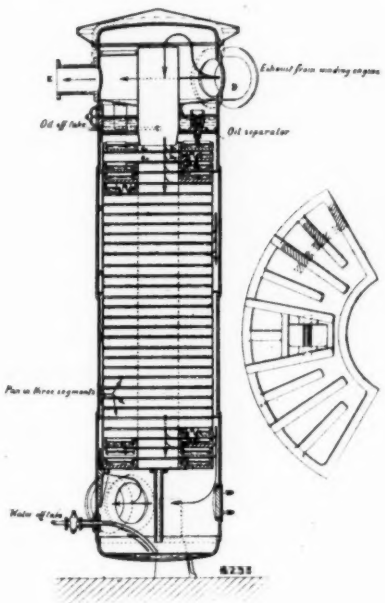


FIG. 1.—CAST-IRON PAN AND WATER ACCUMULATOR-REGENERATOR.

with their major axes vertically, escapes, through small holes in their sides, into the up-takes, where it mingles with the water, thus setting up a very active circulation, while shock is avoided. There is a valve for allowing the steam to escape into the air when not required for the turbine, and also a ball-cock for allowing the water to flow off when the pre-determined level is attained. While the accumulator receives the exhaust steam the water boils violently; but it calms down on the exhaust being interrupted, when it restores the heat absorbed, upon which steam reforms and is disengaged as in a large boiler. Experiments have shown that all the water in the accumulator takes part in the regeneration; and a boiler 6 ms. (20 ft.) long by 2 ms. (6½ ft.) in diameter, containing 10 tons of water, is sufficient, with engine stoppages of a minute, for regenerating 4½ tons of steam per hour.

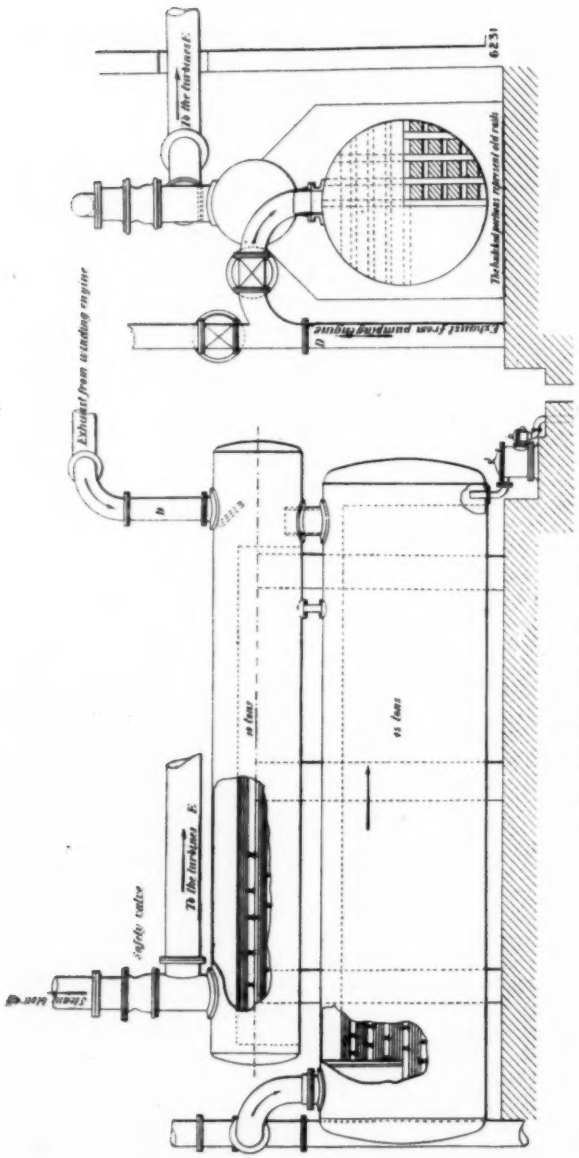


Fig. 2.—DETAILS OF A SCRAP-IRON ACCUMULATOR-REGENERATOR.

Accumulator Fittings.

The following accessories are indispensable for the proper working of a steam accumulator-regenerator plant.

The Discharge Valve, a vertical section of which is shown by Fig. 4, is for allowing direct escape into the air of any steam from the primary engine that may not be required for the turbine, whether the latter work with slight load or be stopped altogether. The valve is double-seated, so as to afford a passage of large sectional area with slight lift, and also for diminishing the steam's thrust, which is counterbalanced by a spiral spring pressing on the valve. The pressure above which the steam is to be allowed to escape into the air, or be sent to a condenser, may be regulated by more or less compressing the spring, through mitre-gear, by hand-wheel from the outside.

Reducing Valve.—It may happen that the primary engine does not afford sufficient steam for ensuring the working of the turbine, or even that there is no exhaust owing to that engine stopping altogether, while the pumps, dynamos, etc., driven by the latter, must continue to work. It is to meet such a case that the adjustable reducing valve is provided, which comes into action automatically

as soon as the pressure in the accumulator falls below a given point.

Owing to the discharge valve and the reducing valve, the primary engine and the turbine are made independent of one another because, if the steam exhausted from the former should be in excess of the latter's requirements, the surplus will be blown off or sent to the condenser, as the case may be : and, inversely, if the quantity of steam regenerated by the accumulator be insufficient to meet the turbine's demands, live steam from the boiler will be admitted by the reducer to supply the deficiency, no matter what be the load on the turbine, and without the engineman's intervention. In this connection it may be observed that there is no disadvantage in drawing on the boilers when the main engine is standing; on the contrary, such a proceeding renders the working more regular.

Steam Stop-valve. — The object of this fitting, which resembles the discharge-valve, and may also be made self-acting, is to shut off the accumulator from the steam turbine when, on the main engine ceasing to work, the turbine draws all its steam supply from the boilers through the expander.

The Water Stop-valve (shown in Fig. 5), which is only required with purely water accumulators, serves to prevent the water from flowing back to the main engine after standing for a long time together.

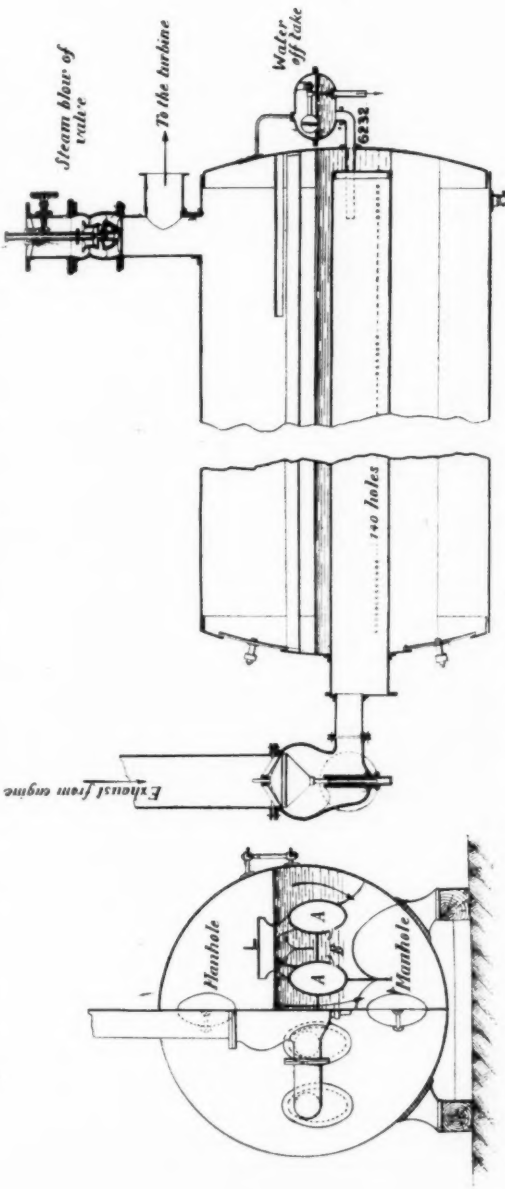


FIG. 3.—DETAILS OF RATEAU'S WATER ACCUMULATOR-REGENERATOR.

Low-pressure Steam Turbines.

In carrying out this method

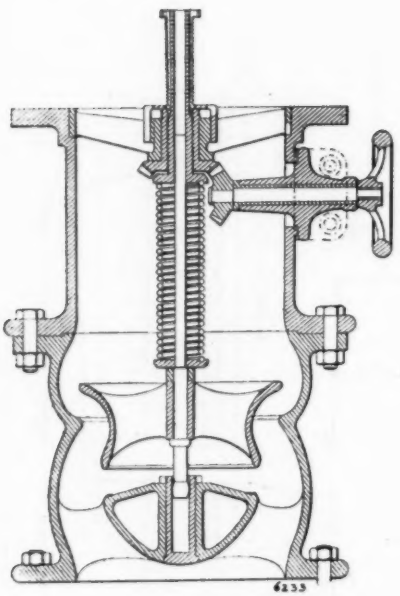


FIG. 4.—VERTICAL SECTION THROUGH STEAM DISCHARGE VALVE.

of intermittent exhaust utilisation any steam turbine may be employed; but the multicellular type, designed by Prof. Rateau in conjunction with Messrs. Sautter, Harlé, et Cie, a 300-h.p. size of which is shown by Fig. 6, coupled to two 500-volt dynamos, has given very satisfactory results in actual running. It consists of several wheels, made of very light steel plate, carrying cylindrical vanes at their periphery, and revolving between circular diaphragms; the latter, provided with distributing floats, being let into grooves in the casing. The bearings are outside the turbine, entrance of air into which is prevented by a special arrangement of brasses.

Where a reciprocating engine would consume about 23 kgs. (50½ lbs.) of steam per effective h.p. per hour, this turbine will only require 14·3 kgs (31½ lbs.), under the supposition that the pressure of the steam entering the turbine is that of the atmosphere, and on leaving it 0·15 kgs. per sq. cm. (2·13 lbs. per sq. in.); that is to say, a vacuum of 65 cms. (26 ins.) of mercury. A good vacuum in the condenser exerts special influence on the steam consumption of low-pressure turbines; and observations made last November on that in question after 15 months' working showed its general efficiency to be exactly the same as when first started.

High- and Low-pressure Steam Turbines.

While the low-pressure turbine is working with live steam from the boiler, previously expanded, its consumption is naturally greater than that of an ordinary engine working with steam at boiler pressure—perhaps 15 kgs. of steam per h.p., instead of 10 to 12 kgs. per h.p. per hour. If the main engine works with tolerable regularity the total admission of live steam will be but slight, and the rather large consumption during that time will exert no great influence on the general economy; but such will not be the case if, for instance, the secondary group (turbine and pump

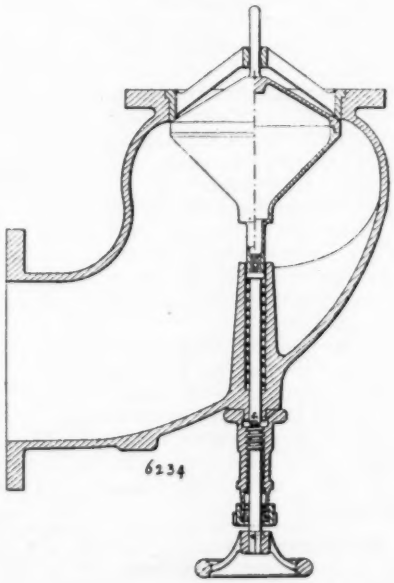


FIG. 5.—SECTION THROUGH WATER STOP-VALVE.

or dynamo) has to work regularly night as well as day.

The turbine may, however, be ensured a working as economical as possible by combining it with a high-pressure turbine for receiving the live steam from the boilers while the main engine is standing; and this steam will afterwards go to the low-pressure turbine, which will thus work indifferently with the exhaust of the high-pressure turbine or steam from the accumulator, the change from one to the other being effected automatically. With an ordinary vacuum such a group will only consume 8 kgs. (17½ lbs.) of steam per electric h.p. per hour, if fully loaded, when working with steam at 8 kgs. per sq. cm. (114 lbs. per sq. in.), and from 12 to 15½ kgs. (26½ to 34 lbs.), according to circumstances, when working with steam exhausted at atmospheric pressure.

Thanks to this simple arrangement, the steam turbines will always work under the most economical conditions. When there is no exhaust from the primary engine they will act like an ordinary high-pressure engine, rationally utilising the live steam; and, on receiving low-pressure steam, they will turn it to account, while proportionally reducing the admission of high-pressure steam. The combined high- and low-pressure turbine may even receive the admission of steam at not merely two, but even three or four different pressures, which would not be easy with a reciprocating engine.

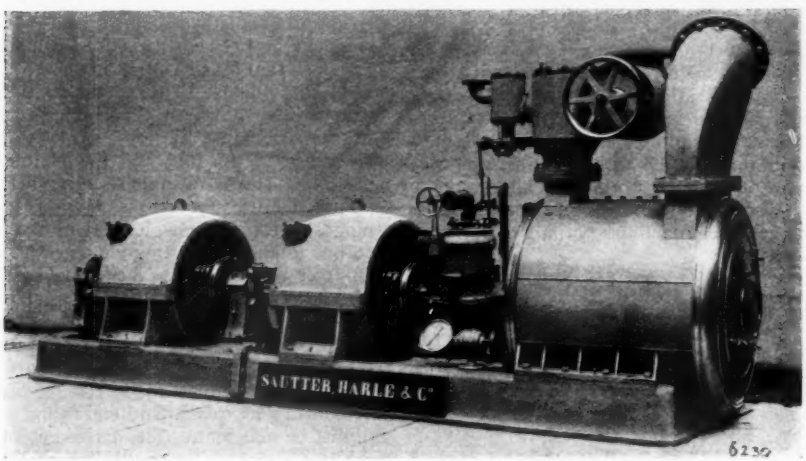


FIG. 6.—COMBINED RATEAU STEAM TURBINE AND DYNAMOS, USED IN CONNECTION WITH THE METHOD OF INTERMITTENT EXHAUST UTILISATION.

Steam Condensation.

After having exerted its effect in the turbines, the steam may be condensed by any of the usual methods. Jet and surface condensers require an air-pump, which, with the circulating pump also required with the latter, must be driven with its own motor, because the turbine generally runs too rapidly to effect this conveniently. No air-pump, however, is required with ejecto condensers, which have the additional advantage of taking up very little room, though they have the disadvantage of not giving quite such a good vacuum as jet and surface condensers; and a greater point must be made to avoid the entrance of air.

Improved Ejecto-condenser.—Fig. 7 shows the form of ejecto-condenser designed by

Prof. Rateau, twenty of which now at work give a vacuum of 62 to 65 cm. (mean 25 ins.) of mercury, according to the quantity and temperature of the feed-water, at the ordinary barometric pressure, while the consumption of water at 53½ degs. Fahr. does not exceed 25 to 30 litres per kg. (mean 2¾ gals. per lb.) of steam condensed. A special arrangement of sluice-valves permits of roughly proportioning the quantity of water to the steam to be condensed, and a retaining valve, always necessary for preventing the water from flowing back towards the motor, is arranged in the appliance itself.

Purposes to which the Recovered Power is Best Applied.

The most frequent application is the generation of electric current, and for this purpose the continuously-revolving steam turbine is superior to the reciprocating engine, while its great regularity of speed does away with a great many causes of irregular working in alternators. The direct coupling of steam turbines with centrifugal pumps permits of raising large volumes of water to great heights by a compact plant of moderate weight and cost, and of high efficiency, while also being trustworthy owing to the absence of parts likely to get out of order.

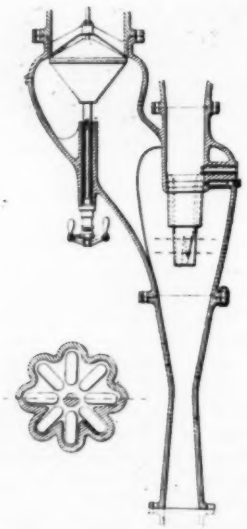


FIG. 7.—DETAILS OF IMPROVED INJECTO-CONDENSER.

Multi-cellular Turbo-pumps. — While centrifugal pumps with a single revolving portion suffice for large volumes and slight heights, Prof. Rateau has designed his "multi-cellular" pumps, with several wheels on the same shaft, for great heights of lift. The example shown by Fig. 8, coupled directly to a steam turbine, raises 180 cub. m. (39,600 gals.) per hour to the height of 210 m. (689 ft.).

Turbo-ventilators.—Steam turbines also lend themselves very readily to the direct-driving of centrifugal fans; and it is evident that the cost of plant on the Rateau system for driving a mine ventilator by the exhaust steam of the winding-engine will cost far less than boilers, etc., put down for that purpose, while there will be no cost for fuel, and the maintenance of a steam turbine is insignificant compared with that of a reciprocating engine. A Rateau helicoidal fan of 25-cm. (10 ins.) diameter, making 20,000 revolutions per minute, with a mechanical yield of about 70 per cent., delivers 0·7 cub. m. (25 cub. ft.) of air per second at a pressure of more than 5·5 m. (18 ft.) of water-column.

For blowing a blast furnace a pressure of about 0·5 kg. per square cm. (7 lbs. per sq. in.) is sufficient. The fan combined with steam turbine on the Rateau system, shown by Fig. 9, is capable of giving 3 cub. m. (106 cub. ft.) of blast per second, that may attain a pressure of 4 ins. (13 ft.) of water-column.

Actual Applications.

The first application of the system was made at Pit No. 5 of the Bruay colleries, in the Pas-de-Calais, France, and the installation (of which Fig. 10 shows a general elevation), started in August, 1902, has not ceased to give the result anticipated. In the words of M. Sohm, engineer of the colliery, "The regenerator works as was foreseen, and the low-pressure turbine runs with the greatest regularity."

The exhaust steam of the winding

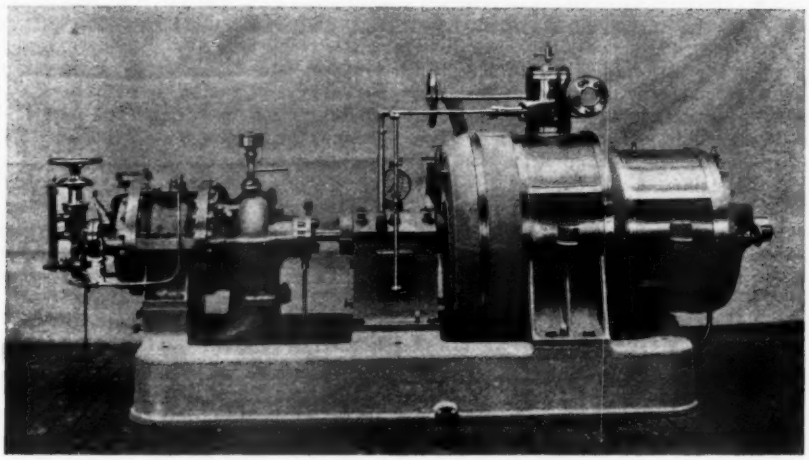


FIG. 8.—COMBINED STEAM TURBINE AND MULTI-CELLULAR PUMP.

engine, and, in this case, of the fan engine also, is passed through oil separators in the accumulator-regenerator itself, which consists of four large cylindrical chambers (like that shown by Fig. 1) containing shallow cast-iron pans that weigh together 40 tons and are filled with water. One of the chambers carries a double-seated discharge-valve (Fig. 4), adjusted to blow off on the pressure exceeding 5 lbs. per sq. in. above atmospheric pressure. At first there were only three chambers; but the fourth was added for diminishing the variations of pressure, because it was found that the stoppages of the winding-engines were longer than had been provided for. The diagrams produced in Fig. 11, giving the pressures in ordinates and the time in abscissæ, were taken by a registering pressure gauge when the accumulator consisted of only three chambers.

This plant is provided with most of the accessories described above, especially the self-acting reducing valve for admitting live steam from the boilers directly into the turbine when the winding-engine stops working for too long a period. The low-pressure turbine with its two continuous-current dynamos (shown by Fig. 6) occupies a ground space of only 5 m. by 1·34 m. (16½ by 4½ ft.), and the additional power they afford is about 300 electric h.p. The table on p. 223 gives the steam consumption at various speeds, and also the efficiency of turbine and dynamos together.

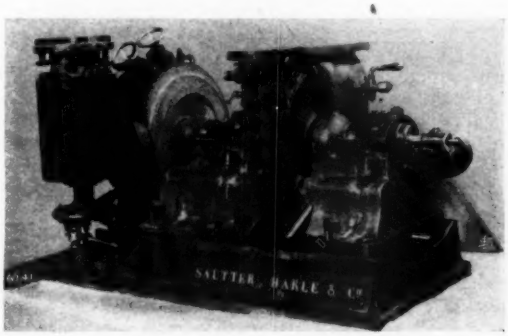


FIG. 9.—COMBINED STEAM TURBINE AND CENTRIFUGAL FAN.

These observations were made before the plant was brought into actual service, and they were checked after it had been working regularly for 15 months, when the general efficiency at the various speeds was found to be exactly the same. With the total yields as ordinates, and the speeds as abscissæ, the curve shown by Fig. 12 was plotted, and continued hypothetically in accordance with the yields observed, showing that they would exceed 60 per cent. with speeds over 2,000 revolutions per minute. Such speeds are easily obtained in practice, and dynamos of 400 to 500 h.p. are now made that run up to 3,000 and even 3,600 revolutions

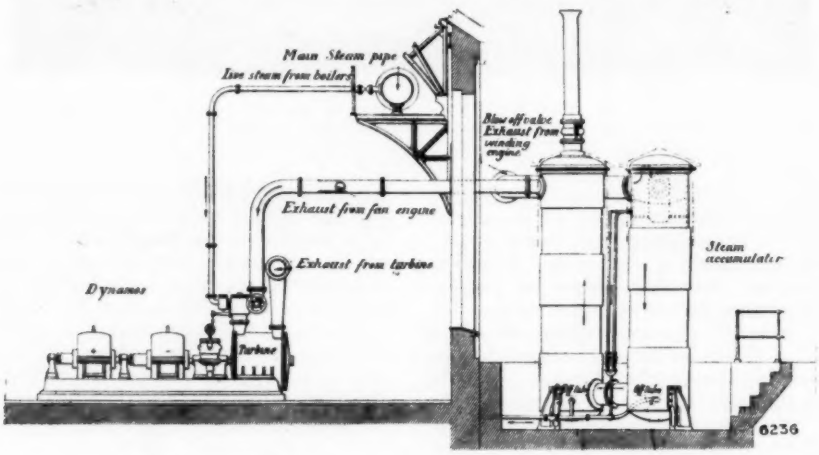


FIG. 10.—STEAM REGENERATION-PLANT AT THE BRUAY COLLIERY, PAS-DE-CALAIS.

per minute. According to the vacuum available, an electric horse-power may be yielded by 12 to 16·5 kgs. (26 to 36 lbs.) of steam per hour, and the obtention of this last-named figure with exhaust steam of only 7½lbs. per sq. in. may be relied upon provided the condenser give a vacuum of 70 cm. (27½ ins.).

At the Reunion Mines, in Spain, the exhaust steam of a winding engine and also of the motor of a Kaselowsky pump is led to an accumulator-regenerator of the simplified type shown by Fig. 2, consisting of a boiler-shell and water-tube

containing 55 tons of old rails. The steam is utilised in two 350-h.p. turbines coupled with 220-kilowatt alternators for tri-phase current up to 1,000 volts. As these turbo-alternators have to work continuously, they are completed by a high-pressure turbine that receives steam directly from a set of boilers at 5 kgs. per sq. cm. (71 lbs. per sq. in.) and another at 12 kgs. (170 lbs.); and the low-pressure turbines exhaust into an ejecto-condenser, which was adopted on account of its simplicity, notwithstanding the comparatively poor vacuum obtained owing to the high temperature of the water with such a hot climate. Nevertheless, a maximum consumption of 17 kgs. (37½ lbs.) per h.p. per hr. is guaranteed when the turbines work with steam of 15 lbs. absolute pressure, and 8·5 kgs. (19 lbs.) when they work exclusively with high-pressure steam.

An exhaust-utilising plant is also being laid down at the Béthune Colliery in the North of France, compressing 60 cub. m. (211 cub. ft.) of free air per minute to a pressure of 6 kgs. per sq. cm. (85 lbs. per sq. in.), for use as motive power in the underground workings. The water accumulator-regenerator (Fig. 3) adopted in this case consists of two boiler-shells,

Observations on 300-h.p. Turbine-Dynamo.

Revolutions per Minute.	Volts.	Amperes	Kilowatts at Terminals	Electric h.p.'s at Terminals	Temperature of Steam.	Absolute Pressures. On Entering.	Absolute Pressures. On Issuing.	Steam Comsumption per h.p. per hour.	Efficiency of turbine and dynamos together*
					degs. Cent.	kgs. per sq. c/m. lbs. per sq. in.	kgs. per sq. c/m. lbs. per sq. in.	kilograms lbs.	
1690 ...	495	385	190·5	259	132°	0·845 = 12	0·156 = 2·2	18·0 = 39½	0·559
1830 ...	503	392	197·5	268·5	132°	0·845 = 12	0·156 = 2·2	17·4 = 38	0·578
1840 ...	503	393	198	269	133°	0·845 = 12	0·156 = 2·2	17·3 = 38	0·581
1700 ...	510	472	240·5	327	135°	1·01 = 14	0·181 = 2·56	17·45 = 28½	0·559
1800 ...	515	480	247	336	135°	1·01 = 14	0·184 = 2·61	16·95 = 37	0·580
1591 ..	505·6	399·6	202	275	137°	0·902 = 12·8	0·163 = 2·318	18·0 = 39½	0·531
1598 ...	503·2	462·1	232·5	316·5	147°	1·034 = 14·28	0·196 = 2·787	17·9 = 39	0·556

* The general efficiency corresponds with the ratio of the electric power, measured at the dynamo terminals, to the energy theoretically contained in the steam utilised, so that it is absolutely net.

The barometric pressure was 755 mm. (29·725 ins.) during the first five observations, 759 mm. (29·882 ins. during the last five.

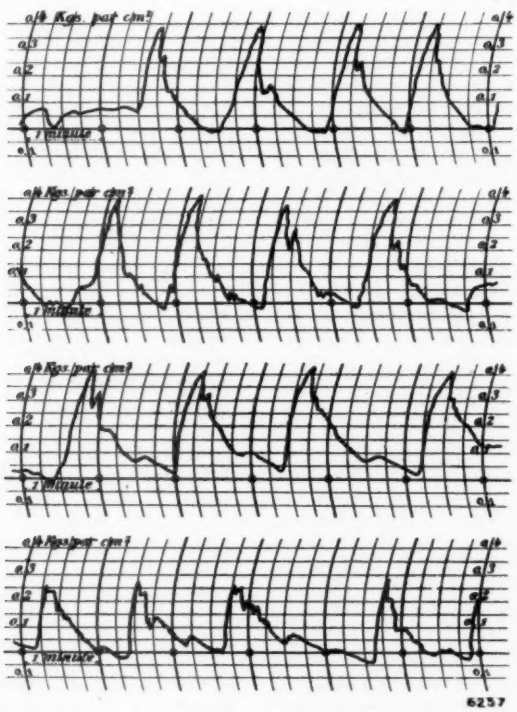


FIG. 11.—PRESSURE DIAGRAMS IN STEAM-ACCUMULATORS.

Ordinates = Pressure in kilograms per square centimetre.
Abscissæ = Time in minutes.

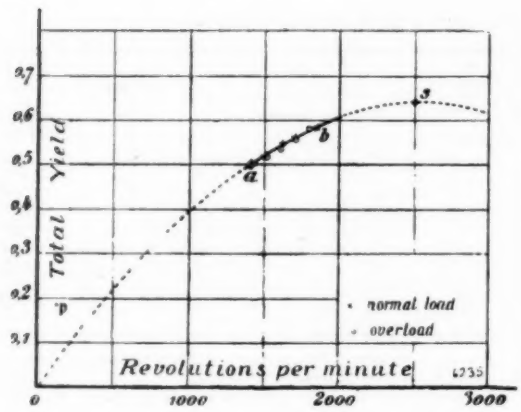


FIG. 12.—CURVE SHOWING EFFICIENCY OF TURBINES AND DYNAMOS AT VARYING SPEEDS.

each containing 10 tons of water. The centrifugal compressor is constituted by several Rateau fans mounted on the same shaft as the low-pressure steam turbine, for receiving steam directly from the boilers at a pressure of 6 kgs. per sq. cm. (85 lbs. per sq. in.). The exhaust steam from the turbines will be sent to a central condenser, which affords a vacuum of 65 cm. (25½ ins.) of mercury. The consumption of low-pressure steam per h.p. per effective hour in compressed air will not exceed 26 kgs. (46 lbs.).

Application to Iron and Steel Works.

Although the first applications of this system have been made at mines, it is just as much indicated for iron and steel works; and, indeed, in their case, the exhaust utilising plant is likely to be even more remunerative, and be more quickly paid off, since steam-hammers and rolling mills generally work both night and day. The reversing engines of roll-trains often consume as much as 20 tons of steam per hr., so that, as the combined turbine and dynamo only requires 14 kgs. (30¾ lbs.) per electric h.p. per hr., over 1,000 e.h.p. may be obtained gratuitously; and more frequently than not the exhaust steam of all the steam-hammers, roll-trains, and other engines may be sent to a central station for generating electric current.

If we call Q the weight in kilogrammes of dry steam recovered in tons per hour, the additional power afforded will be $\frac{1}{14} Q$: and, as Q often exceeds 60 tons, iron and steel works of average size may obtain an increase of 4,000 h.p. at very slight cost.

The Saving Effected

is of two orders—in first cost and current expense:—

In the Cost of Plant.—This saving is chiefly due to the suppression of boilers that would have to be laid down for obtaining the power afforded by the accumulator-regenerator, the cost of which is far less; and again, the steam turbine is much cheaper than an equivalent reciprocating engine. For the production of 500 h.p., a sum of 60,000 frs. (£2,400) may be saved by adopting the Rateau system.

In Current Expense. — The saving under this head mainly results from there being no necessity to burn fuel for producing the additional power during the time that the existing engine works, in addition to which stokers' wages are saved and the charge for sinking fund is greatly reduced. If it be supposed that the existing engine works on an average at four-fifths of its power for ten hours a day and permits the recovery of 500 electric h.p., calculations based on actual data show that a yearly saving may be effected of 25,200 frs. in fuel, 7,000 frs. in sinking fund, 3,600 frs. in stokers' wages, making a total of 35,800 frs. (£1,400), to say nothing of lubrication.

In the case of steelworks the saving would be even greater — probably more than double—for the same power recovered, calculated on 24 hours' working. The engines at steelworks are more numerous, more concentrated and more various than at mines, while the coal burnt is of higher quality and therefore more expensive.

Modern Woodworking Machinery.

By M. POWIS BALE, A.M.Inst.C.E., M.I.Mech.E.

(*Continued from page 138.*)

Deal Frames.

MANY of my notes on ordinary log frames will apply equally well to deal frames. In addition we may say, however, that for rapid sawing many double deal frames are now made with the swing frames working in equilibrium; that is, counterbalancing each other, thus enabling a higher rate of speed to be obtained with safety. For high-speed sawing, and to avoid marking the deals, a compound feed with plain vertical-driven rollers can be recommended. The speed of the feed is usually from 1 ft. 6 ins. to 7 ft. 6 ins. per minute; while that of the saw is from 500 to 900 ft. per minute, according to the construction of the machine.

Fig. 11 represents a high-speed deal and flitch frame for re-sawing deals into boards (by Messrs. A. Ransome & Co., Limited, Newark-on-Trent). This frame is constructed on the equilibrium principle, and is fitted with two separate swing-frames worked from one double-throw crank-shaft, with the cranks arranged opposite one another, so that when in action the frames counterbalance each other, thus obviating the use of a counterbalanced fly-wheel, and at the same time enabling a considerably higher rate of speed to be attained without excessive vibration. Each swing frame is fitted with a separate vertical roller-driven feed-motion, which can be readily varied in speed to suit the nature of the work or the number of saws employed.

The rollers on the fence side of the deals are constructed so as to allow of the ready vertical adjustment of the upper fence-bar to suit battens, deals, or planks.

The frame is driven from pulleys at each end of the crank shaft. The speed of feed is from 1 to 6 ft. per minute.

Fig. 12 shows a roller-feed band-sawing machine for re-sawing deals, flitches, etc., into boards (by Messrs. W. B. Haigh & Co., Limited, Oldham). The feed consists of four vertical rollers, two plain and two fluted, the fluted rollers being driven by spur and bevel gearing. The plain-feed rollers and fence are mounted in a slide, and are readily adjustable to or from the saw to suit the different thicknesses of boards to be sawn. The top saw-wheel runs in two pairs of bearings fitted in a U bracket, and is made to cant. When it is required to use the machine as an ordinary hand-feed band-saw, the automatic feed gear can be readily dismounted from the table. In lieu of the feed gear these machines are sometimes arranged with a travelling table.

Ordinary Band-Sawing Machinery.

Some of my notes on the construction of log band-sawing machines will apply to those of ordinary construction where the wood is fed through the saw by hand. The main frame should be rigid, and by preference cast in one piece: hollow or box framing is to be preferred. The frame should be bowed to allow of ample space for the manipulation of the wood, and the base plate extended. The saw-wheels should be of as large a diameter as may be convenient—certainly not less than 30 ins.—and as light and strong as possible, and be perfectly in balance. Steel or wrought-iron wheels made somewhat after the fashion of bicycle wheels are to be preferred to cast-iron ones. The top saw-wheel should be mounted elastically, and arranged to cant. Arrangements should also be made to keep the saw to to its proper tension. This is usually

done by means of a weighted counter-balanced lever or spring fitted to the top slide.

Metallic friction guide-wheels can be recommended for receiving the back thrust of the saw, and the saw-table be made to cant to any desired angle by means of a hand wheel, worm, and worm quadrant. For heavy bevel sawing, the column of the machine itself can be arranged to cant with advantage.

Saws of this description—running on wheels less than 3 ft. diameter—have a speed of about 4,000 ft. per minute, and those of from 3 ft. to 4 ft. diameter 5,000 ft. per minute.

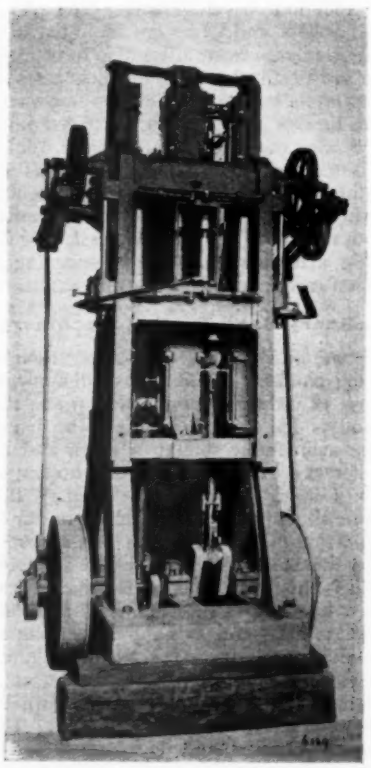


FIG. 11.—HIGH-SPEED DEAL AND FLITCH FRAME BY MESSRS. A. RANSOME AND CO., LTD., NEWARK.

Fig. 13 shows a motor-driven band-saw from the designs of Messrs. W. B. Haigh & Co., Ltd., Oldham. The main frame is a cored casting made in one piece The saw-wheels are of wrought iron faced with indiarubber—the top wheel being arranged to rise and fall and cant, so as to adjust itself to different lengths and widths of saws. The bottom saw-wheel runs in adjustable gun-metal bearings fi ted to the main frame. The saw tension arrangement consists of a lever and weights fitted to the top saw-wheel slide. The table is made to cant for bevel sawing by means of a quadrant and worm and worm-wheel.

The motor is mounted on an extension of the base-plate, and connected to the lower saw pulley-shaft by a gear-wheel driven by a machine-cut pinion-wheel made of hard vulcanised fibre or raw hide.

The makers sometimes fit, instead of the above, a slow-speed motor with its armature shaft coupled directly to the lower-saw pulley-shaft — an arrangement which is to be preferred.

Circular Saw Benches.

Circular saw benches of various kinds are more largely used than any other machines for converting wood. Their general design is well-known, but as many very poor ones are on the market a few general remarks on points to be desired in their construction may not be out of place.

The main frame of the bench should be cast in one piece on the "box" system and the pedestals to receive the bearings cast solid with the frame. Bearings of gun-metal or phosphor-bronze and of ample length, say three diameters of saw-spindle. Three sets of bearings to be provided for saws of 36 ins. diam. and upwards, one being placed outside the driving-pulleys to withstand the pull of the belt. In the case of heavy benches it will be found convenient to let the bearings in from the face of the bench instead of from beneath the table-top, movable plates being fitted to allow of ready access to the spindle.

The saw-spindle should consist of steel and be fitted with lock-nuts to take up wear. The loose pulley can be made of

slightly less diameter than the fast, to relieve the tension of the belt when not in use, or special means should be taken for its lubrication.

The fence in most benches should be made to turn over to allow of cross-cutting and angle for feather-edge-cutting and be fitted with fine adjustment-screw and the front plate made to slide to suit saws of varying diameter. The fence also should be fitted with adjustable anti-friction strips or rollers, according to the nature of the work. In heavy benches a roller to carry the timber fitted to the end of the frame is an advantage.

In the case of rack-feed benches the travelling table should be made of wrought-iron and be fitted with a quick return motion. In machines of recent construction the gearing for working the feed and return motions is attached to the frame of the bench itself, which reduces the amount of excavation necessary, and for rapid work the log is held by adjustable

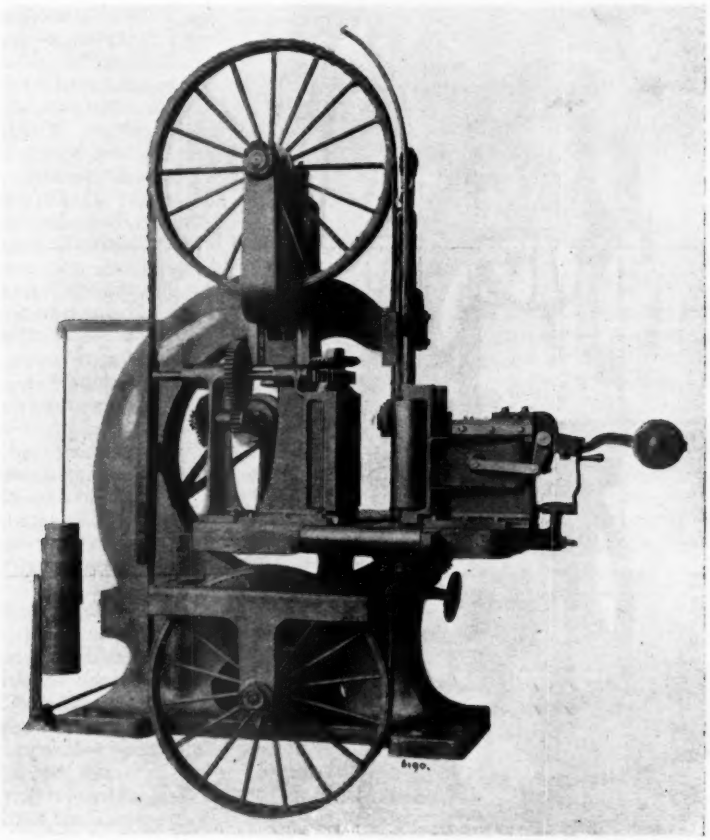


FIG. 12.—ROLLER-FEED BAND-SAWING MACHINE BY MESSRS. W. B. HAIGH AND CO., LTD., OLDHAM.

dogs worked by eccentric levers, and it is quickly presented to the saw after each cut. Although rack benches consume a large amount of power for converting heavy logs into scantlings, for railway work, etc., they are very expeditious and useful.

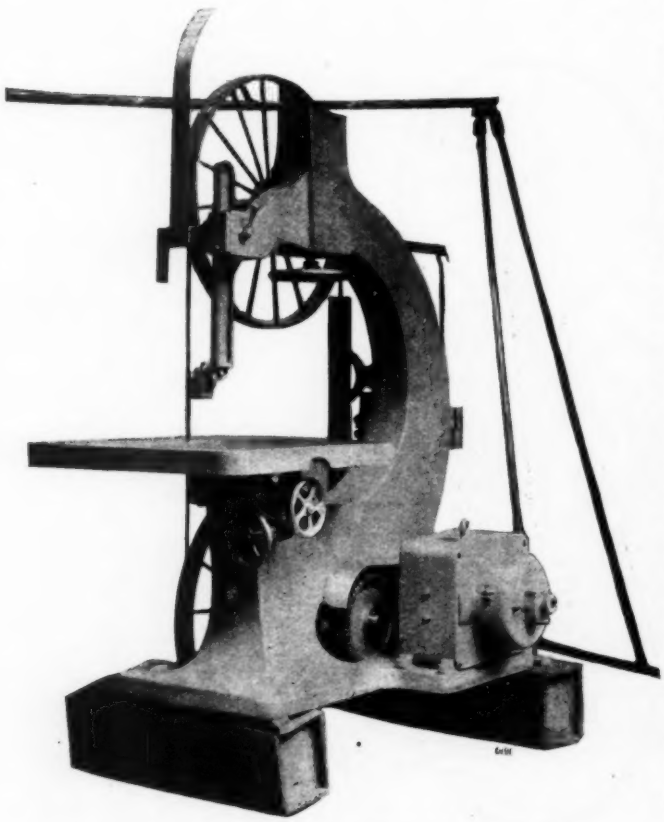


FIG. 13.—MOTOR-DRIVEN BAND-SAW BY MESSRS. W. B. HAIGH AND CO., LTD., OLDHAM.

The feed gears used on saw benches are (1) the rope, (2) the chain, (3) the roller, (4) the rack.

(1) *The Rope Feed* is the one most generally used, but has the disadvantage of being intermittent. It should be driven from the saw spindle so as to be always in proportion to the speed of the saw, and should be readily variable at, say, from 5 ft. to 50 ft. per minute to suit different classes of work and kinds of timber.

(2) *The Endless Chain* is a powerful feed, and is especially adapted for sleeper and other uniform sawing of moderate length. The chain is a pitched one and fitted with adjustable dogs. The speed of feed is 16 ft. to 50 ft. per minute.

(3) *Driven-Roller Feeds* have of late come into extended use, and they have the advantage of being continuous and are especially adapted for re-sawing deals, battens, etc., which they can do much faster than a rope or other feed bench, but are unsuitable for round timber.

It is important in the construction of these feeds that they can be readily brought into action, be adjusted to different diameters of saws, or moved out of the way so that the machine can be used as an ordinary bench. A series of adjustable "live" rollers should be fitted to the fence, as the friction of the wood passing through the saw is considerably reduced thereby. Where much moulding stuff is cut the feed rollers should be arranged to angle. The speed of feed is from 30 ft. to 90 ft. per minute.

(4) *Rack Feed.*—This is a powerful and certain feed, and one well adapted for

heavy work, etc. It is important that the rack and pinion be very carefully made and pitched, or the table may jump and ride on the pinion. To obviate this some makers construct the pinion to gear vertically into the rack. In very large machines a pair of racks can be used with advantage. The rollers and spindles supporting the table should be properly turned and fitted, so as to secure an even motion when running. In America a friction-wheel feed is often employed for traversing these tables. The speed of feed is from 5 ft. to 50 ft. per minute. "Swaged" or spread set saw teeth will stand a quicker feed than spring set.

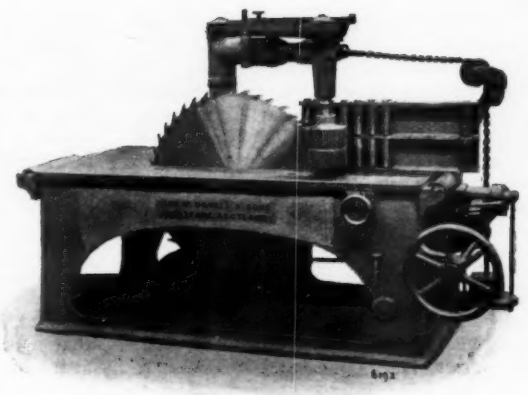


FIG. 14.—AUTOMATIC CONTINUOUS ROLLER-FEED SAW-BENCH BY MESSRS. JOHN MCDOWALL AND SONS, JOHNSTONE.

Speed of Circular Saws.

For ripping 9,000 ft. per minute.

For cross-cutting 10,000 ft. per minute.

Fig. 14 shows an automatic continuous roller-feed saw-bench for sawing deals, battens, etc., into boards, from the designs of Messrs. John McDowall & Sons, Johnstone.

The frame of the bench is cast in one piece, and the saw-spindle runs in three sets of bearings, the one outside the driving pulleys being self-contained with the bench.

The pivot for the radial arm is placed out of the way at the back of the bench. This arm can be advanced or retired to suit varying diameters of saws, or swung out of the way so that the bench can be used for jobbing purposes. The feed gear is driven from the saw-spindle and is therefore always in ratio to the speed of the saw. It is arranged with four rates of speed, from 15 ft. to 60 ft. per minute. A worm and quadrant motion is fitted to the radial arm for bringing the feed roller to bear properly on feather-edged or badly sawn boards. For angular sawing, an angling fence and special conical shaped feed-roller are fitted. The bench is suitable for either deep or flat cutting, and the makers claim that it is capable of sawing 25,000 lineal feet of 9-in. deals into boards in a day of ten hours.

Fig. 15 shows a patent circular re-sawing machine, as made by a Stockholm firm. The main frame of this machine is cast in one piece, and the saw-spindle is so mounted that it can be readily adjusted

FIG. 15.—CIRCULAR RE-SAWING MACHINE BY MESSRS. J. AND C. BOLINDERS.

to or from the feed-roller to suit different diameters of saws. The feed gear consists of one vertical grooved roller of large dimensions, faced by two plain ones of less diameter. The pressure of the main feed-roller is regulated by means of a lever and counter-weight, and the opposite rollers are adjustable to or from each other, to or from the fence, and before and after the centre of the feed-roller—enabling the workman to regulate the feed of the board whilst the machine is running. Additional adjustable pressure rollers for holding the wood steady are also fitted immediately in front of the saw-blade. The feed and pressure rollers are independent of each other, and can be adjusted to different angles for cutting feather-edged boards, etc. Adjustable packing-boxes are fitted on both sides of the front half of the saw, and set screws at the back half. The saw spindle is driven from a countershaft placed below the machine, and, instead of the ordinary fast and loose pulleys, is fitted with a four-speed cone.

This machine is designed especially for re-sawing deals into boards, and "ground off" saws up to as fine as 23 B.W.G. can be used, and it is claimed by the makers that it is capable of cutting 7-in. boards at the high rate of 150 run per minute.

(To be continued.)

Experiments with Rapid-Cutting Steel Tools.*

TABLE XII.—HARD CAST IRON.

1	2	3	4	5	6	7	8	9	10	11
Tool Steel Maker.	No. of Trial.	Front Cutting Angle $90°-(\beta+f')$.	Front Top Rake. $(\beta+f')$.	Front Clearance Angle. (C').	Side Cutting Angle. $(90-s)$.	True Cutting Angle. {90—(Top rake in this plane + β).} At Start.	True Cutting Angle. {90—(Top rake in this plane + β).} At Finish.	Height of Tool above Centre.	(β).	Cutting Arc.
		Deg. Min.	Deg. Min.	Deg. Min.	Deg. Min.	Deg. Min.			Deg. Min.	Inches.
Object of Trial :—To obtain Maximum Cutting Speed.										
A. W. ...	107	83 35	6 25	8 32	87 10	83 35	.....	.....	.....	0·25
Bu.	190	74 35	15 25	7 28	.....	71 15	.....	0·125	2 3	0·15
Br.	113	76 9	13 51	11 19	84 17	74 47	.....	0·25	2 32	0·2
Ca.	109	76 26	13 34	9 56	82 10	73 43	.....	0·125	1 14	0·12
Fi.	117	78 9	11 51	11 19	78 41	75 3	.....	0·25	2 37	0·20
Os.	121	76 59	13 1	7 50	75 57	72 37	.....	0·0625	0 41	0·22
S. D. ...	111	78 51	11 9	9 56	81 50	76 46	.....	0·125	1 14	0·20
Object of Trial :—To obtain Maximum Cutting Speed.										
A. W. ...	108	76 38	13 22	9 56	88 55	84 18	.....	.....	.....	0·375
Bu.	191	77 19	12 41	7 28	.....	75 38	.....	.....	.....	0·50
Br.	114	76 4	13 56	11 19	82 52	75 23	.....	0·25	2 37	0·40
Ca.	110	76 28	13 32	19 20	75 20	73 46	.....	0·1875	1 52	0·35
Fi.	120	74 28	15 32	14 3	72 0	70 25	.....	0·3125	3 32	0·425
Os.	122	80 48	9 12	10 37	71 20	71 35	.....	0·0625	0 44	0·50
S. D. ...	112	76 45	13 15	9 56	83 55	75 23	.....	0·125	1 15	0·36
Object of Trial :—To Machine Maximum Area of Surface.										
A. W. ...	125	80 46	9 14	8 32	87 10	82 10	.....	.....	.....	0·41
Bu.	189	75 5	14 55	7 28	.....	72 2	.....	0·125	1 55	0·54
Br.	115	77 30	12 30	14 3	83 55	77 30	.....	0·250	2 35	0·38
Ca.	129	75 29	14 31	11 19	80 4	74 8	.....	0·0625	0 49	0·52
Fi.	118	71 53	18 7	11 39	76 18	67 18	.....	0·3125	3 24	0·42
Os.	124	77 36	12 24	8 32	73 57	73 13	.....	0·0625	0 44	0·52
S. D. ...	127	78 37	11 23	10 37	79 44	76 33	.....	0·0625	0 46	0·39
Object of Trial :—To Remove Maximum Weight per minute.										
A. W. ...	126	81 28	8 32	7 50	90 0	85 0	.....	.....	.....	0·675
Bu.	188	72 21	17 39	7 28	.....	73 1	.....	0·25	3 37	0·875
Br.	116	74 31	15 29	12 41	82 52	74 31	.....	0·25	2 48	0·61
Ca.	130	84 18	5 42	10 58	80 46	77 40	.....	.....	.....	0·66
Fi.	119	73 54	16 6	9 56	74 35	68 33	.....	0·3125	3 46	0·61
Os.	123	77 40	12 20	5 43	72 0	71 40	.....	.....	.....	.....
S. D. ...	128	80 12	9 48	7 8	81 28	76 45	.....	0·0625	0 55	0·675

* Continued from page 164.

TABLE XIII.—SOFT STEEL.

1	2	3	4	5	6	7	8	9	10	11
Tool Steel Maker.	No. of Tool.	Horse Power Electrically Measured. Gross.	Lost.	Net.	Corrected Net.	Average Cutting Speed.	Cutting Force on Point of Tool.	Area of Cut.	Mean Revs. of Motor.	Gear and Cone Step in use.
Object of Trial :—To obtain Maximum Cutting Speed.										
						Ft. per min.	Lbs.	Sq. in.	P. min	*
A. W..	1	16·1	13·70	2·4	. ...	193·0	410	0·00338	260	Ds.
Bu. ...	9	12·03	9·92	2·11	.....	106·0	657	0·00365	224	Dm.
Br. ...	7	———	——Not	Taken—	———	163·5	———	0·00381	220	Ds.
Ca. ...	13	15·65	11·94	3·71	.....	149·2	821	0·00325	215	,,
Fi. ...	5	14·07	9·40	4·67	.....	128·0	1,210	0·00367	260	Dm.
Os. ...	3	13·00	9·37	3·63	.....	114·0	1,050	0·00344	224	,,
S. D. .	15	14·80	10·45	4·35	.....	124·5	1,150	0·00372	258	,,
V. M.	11	16·30	12·82	3·48	.....	132·5	867	0·00362	288	,,
Average		14·58	.....	.....	.....	138·8	881	0·00357	.....	.....
							110 tons per sq. in.			
Object of Trial :—To obtain Maximum Cutting Speed.										
A. W..	2	18·90	9·80	9·10	.....	111·0	2,705	0·01060	220	Dm.
Bu. ...	10	18·30	9·60	8·70	.....	108·0	2,660	0·01058	228	,,
Br. ...	8	17·45	10·45	7·00	.....	98·6	2,440	0·01280	230	,,
Ca. ...	14	21·80	10·75	11·05	.....	121·0	3,020	0·01096	252	,,
Fi. ...	6	17·25	10·12	7·13	.....	93·5	2,522	0·01018	255	Dl.
Os. ...	4	14·76	8·36	6·40	.....	83·0	2,543	0·01038	231	,,
S. D. .	16	15·75	8·00	7·75	.....	100·9	2,530	0·01060	210	Dm.
V. M..	12	19·40	10·24	9·16	.....	106·4	2,840	0·01040	225	,,
Average		17·95	.....	.....	.....	102·8	2,658	0·01081	.....	.....
							110 tons per sq. in.			
Object of Trial :—To Machine Maximum Area of Surface.										
A. W..	38	18·50	6·74	11·76	.....	74·00	5,240	0·02150	190	Dm.
Bu. ...	31	14·88	7·71	7·17	.....	38·73	6,110	0·02260	250	Tm.
Br. ...	40	16·10	7·16	8·94	.....	63·50	4,650	0·01990	220	Dl.
Ca. ...	29	21·05	10·54	10·51	.....	61·06	5,680	0·01990	264	Ts.
Fi. ...	35	17·90	7·12	10·78	.....	66·60	5,425	0·02155	220	Dl.
Os. ...	27	21·00	8·60	12·40	.. ...	72·88	5,620	0·02035	225	,,
S. D. .	33	20·20	10·50	9·70	.....	52·20	6,130	0·01850	258	Ts.
V. M..	.....	Retired	from	Trials	.....	.....	.....	.....	.....	.....
Average		18·52	.....	.....	.....	61·28	5,551	0·02061	.....	.....
							120 tons per sq. in.			
Object of Trial :—To Remove Maximum Weight per minute.										
A. W..	39	28·30	12·250	16·050	.....	54·50	9,720	0·04010	210	Dl.
Bu. ...	32	19·30	7·970	11·330	.....	28·96	12,920	0·04630	260	Tl.
Br. ...	41	26·00	9·275	16·725	.....	50·75	10,860	0·04340	265	Ts.
Ca. ...	30	25·20	8·010	17·190	.....	37·35	15,200	0·04625	240	Tm.
Fi. ...	36	26·20	10·460	15·740	.....	52·50	9,900	0·03680	250	Ts.
Os. ...	28	23·10	8·250	14·850	... .	49·30	9,960	0·04040	220	,,
S. D. .	34	24·45	8·640	15·810	.....	38·30	13,625	0·04230	260	Tm.
V. M. .	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average		24.65	.....	.....	.....	44·52	11,740	0·04222	.....	.....
							124 tons per sq. in.			

* D = Double Gear. T = Treble Gear.
s = Small, m = Middle, l = Large } Cone Step.

TABLE XIV.—MEDIUM STEEL.

1	2	3	4	5	6	7	8	9	10	11
Tool Steel Maker.	No. of Trial.	Horse Power Electrically Measured. Gross.	Lost.	Net.	Corrected Net.	Average Cutting Speed.	Cutting Force on Point of Tool.	Area of Cut.	Mean Revs. of Motor.	Gear and Cone Step in use.
Object of Trial :—To obtain Maximum Cutting Speed.										
						Ft. per min.	Lbs.	Sq. in.	P. min.	
A. W..	79	11·120	8·40	2·720	2·125	109·0	643	0·00225	250	Dm.
Bu. ...	91	11·360	7·73	3·630	2·710	105·0	853	0·00384	270	,,
Br. ...	83	9·575	6·455	3·140	3·140	102·0	1,015	0·00397	232	,,
Ca. ...	89	11·150	7·640	3·510	3·095	104·5	977	0·00375	265	,,
Fi. ...	81	12·520	9·190	3·330	3·145	105·2	985	0·00390	238	,,
Os. ...	87	11·900	8·850	3·050	2·525	93·0	898	0·00384	300	,,
S. D. .	85	10·025	6·600	3·425	3·130	93·5	1,105	0·00378	225	,,
Average		11·097	.....	.....	.....	101·7	925	0·00362	.....	.....
							114 tons per sq. in.			
Object of Trial :—To obtain Maximum Cutting Speed.										
A. W..	80	13·48	8·160	5·32	.....	67·5	2,600	0·01190	215	Dl.
Bu. ...	92	12·10	6·550	5·55	.....	89·5	2,047	0·01220	215	Dm.
Br. ...	84	15·50	9·660	5·84	.....	74·7	2,580	0·01148	252	Dl.
Ca. ...	90	14·40	7·720	6·68	.....	80·0	2,755	0·01140	226	Dm.
Fi. ...	82	15·98	10·270	5·71	.....	81·6	2,307	0·01162	250	Dl.
Os. ...	88	13·90	8·500	5·40	.....	70·5	2,530	0·01120	240	Dm.
S. D. .	86	13·69	7·160	6·53	.....	66·5	3,250	0·01150	230	Dl.
Average		14·15	.....	.....	.....	75·8	2,581	0·01161	.....	.....
							99·3 tons per sq. in.			
Object of Trial :—To Machine Maximum Area of Surface.										
A. W..	95	19·22	9·94	9·28	9·0	48·5	6,125	0·02140	254	Ts.
Bu. ...	94	17·20	8·83	8·37	.....	54·1	5,100	0·02250	280	,,
Br. ...	99	18·00	9·65	8·35	.....	49·4	5,570	0·02150	276	,,
Ca. ...	102	15·91	6·72	9·19	.....	61·2	4,955	0·02290	200	Dm.
Fi. ...	97	19·10	10·55	8·55	.....	51·5	5,480	0 02270	280	Ts.
Os. ...	103	14·70	6·75	7·95	.....	49·9	5,250	0·02175	235	Dl.
S. D. .	105	16·10	7·00	9·10	.....	51·4	5,850	0·02275	230	,,
Average		17·176	.....	.....	.....	52·3	5,480	0·02222	.....	.....
							110 tons per sq. in.			
Object of Trial :—To remove Maximum Weight per minute.										
A. W..	96	20·45	7·38	13·07	.....	39·0	11,050	0·04180	214	Ts.
Bu. ...	93	19·00	7·65	11·35	.....	36·0	10,460	0·04365	260	Tm.
Br. ..	100	19·90	7·63	12·27	.....	37·9	10,680	0·04325	220	Ts.
Ca. ...	101	.....	.....	.....	.....	38·5	.....	0·04120	200	Dl.
Fi. ...	98	18·80	7·42	11·38	.....	36·6	10,250	0·04080	205	Ts.
Os. ...	104	18·75	6·90	11·85	.....	37·5	10,400	0·04320	213	,,
S. D. .	106	21·16	9·65	11·51	.....	38·6	9,840	0·04250	270	,,
Average		19·78	.....	.....	.....	37·7	10,446	0·04234	.....	.....
							110·2 tons per sq. in.			

TABLE XV.—HARD STEEL.

1	2	3	4	5	6	7	8	9	10	11
Tool Steel Maker.	No. of Trial.	Horse Power. Electrically Measured. Gross.	Lost.	Net.	Corrected Net.	Average Cutting Speed.	Cutting Force on Point of Tool.	Area of Cut.	Mean Revs. of Motor.	Gear and Cone Step in use.
Object of Trial:—To obtain Maximum Cutting Speed.										
						Ft. per min.	Lbs.	Sq. in.	P. min.	
A. W.	139	9·30	7·10	2·20	1·685	52·50	1,172	0·00397	220	Dl.
Bu. ...	143	10·25	8·10	2·15	2·150	59·50	1,190	0·00412	250	,,
Br. ...	133	12·45	10·03	2·42	1·845	49·75	1,225	0·00390	285	Ts.
Ca. ...	137	11·10	8·28	2·82	2·610	58·00	1,488	0·00362	240	Dl.
Fi. ...	131	13·60	10·24	3·36	2·100	46·80	1,480	0·00328	270	Ts.
Os. ...	141	10·50	7·87	2·63	2·075	56·20	1,218	0·00381	235	Dl.
S. D.	135	13·24	9·45	3·79	2·905	59·10	1,620	0·00359	250	,,
Average		.....	.....	.....	.. ...	54·5	1,342 (160 tons per sq. in.)	0·003744	.. ...	.....
Object of Trial:—To obtain Maximum Cutting Speed.										
A. W.	140	13·13	8·370	4·76	.....	40·0	3,925	0·0119	240	Ts.
Bu. ..	144	13·80	8·70	5·10	.....	41·2	4,080	0·0124	250	Dl.
Br. ...	134	13·66	8·88	4·78	.....	42·5	3,720	0·0120	244	Ts.
Ca. ...	138	13·10	8·10	5·00	.....	40·5	4,075	0·01173	240	,,
Fi. ...	132	12·95	9·300	3·65	.....	40·6	2,970	0·0117	230	,,
Os. ...	142	13·15	8·10	5·05	.....	38·8	4,340	0·0117	240	,,
S. D.	136	15·19	10·05	5·14	.....	43·5	3,900	0·0116	250	,,
Average		.....	.....	.....	.....	41·0	3,858 (145·5 tons per sq. in.)	0·01186	.....	.....
Object of Trial:—To Machine Maximum Area of Surface.										
A. W.	153	15·30	7·87	7·43	.....	30·8	7,960	0·0219	215	Ts.
Bu. ...	155	14·60	8·40	6·20	.....	30·7	6,664	0·02345	235	,,
Br. ...	145	16·80	9·65	7·15	.....	31·9	7,400	0·0234	204	,,
Ca. ...	149	15·90	8·05	7·85	.....	32·6	7,950	0·0229	205	,,
Fi. ...	157	14·68	8·78	5·90	.....	30·0	6,490	0·02265	230	,,
Os. ...	151	12·70	6·55	6·15	.....	29·9	6,800	0·0230	194	,,
S. D.	147	12·55	6·20	6·35	.....	26·8	7,850	0·0239	178	,,
Average		.....	.....	.....	.....	30·4	7,302 (142·3 tons per sq. in.)	0·0230	.....	.....
Object of Trial:—To remove Maximum Weight per minute.										
A. W.	154	16·68	7·00	9·68	.....	20·8	15,357	0·0452	230	Tm.
Bu. ...	156	14·60	7·00	7·60	.....	18·7	13,412	0·0464	229	,,
Br. ...	146	17·80	7·30	10·50	.....	20·0	17,300	0·0410	200	Tl.
Ca. ...	150	15·90	6·95	8·95	.....	20 0	14,800	0·0441	210	Tm.
Fi. ...	158	16·40	6·87	9·53	.....	20·0	15,724	0·0429	235	,,
Os. ...	152	14·50	6·30	8·20	.....	20·15	13,300	0·0452	200	,,
S. D.	148	16·40	7·52	8·88	.....	17·60	16,650	0·0415	247	Tl.
Average		.....	.....	.....	.....	19·61	15,220 (155·2 tons per sq. in.)	0·0438	.....	.....

TABLE XVI.—SOFT CAST IRON.

1	2	3	4	5	6	7	8	9	10	11
Tool Steel Maker.	No. of Trial.	Horse Power Electrically Measured. Gross.	Lost.	Net.	Corrected Net.	Average Cutting Speed.	Cutting Force on Point of Tool.	Area of Cut.	Mean Revs. of Motor.	Gear and Cone Step in use.
Object of Trial:—To obtain Maximum Cutting Speed.										
						Ft. per min.	Lbs.	Sq. in.	P. min.	
A. W.	167	8·76	7·15	1·61	1·330	101·5	432	0·00409	105	Dm.
Bu. ...	165	9·25	7·40	1·85	1·645	112·0	485	0·00375	215	,,
Br. ...	171	9·06	6·95	2·11	1·940	107·0	598	0·00397	220	,,
Ca. ...	161	9·77	7·45	2·32	.....	109·0	700	0·00390	215	,,
Fi. ...	170	9·35	7·20	2·15	.....	107·0	665	0·00400	215	,,
Os. ...	163	12·50	9·67	2·83	... ..	103·5	631	0·00118	218	,,
S. D.	159	10·40	6·40	1·00	1·980	103·5	225	0·00394	202	,,
Average		9·87	.....	.. ..	0·725	106·2	534 (67·2 tons per sq. in.)	0·00355	.....	.....
Object of Trial:—To obtain Maximum Cutting Speed.										
A. W.	168	10·10	7·90	2·20	.....	89·0	815	0·0124	180	Dm.
Bu. ...	166	9·75	6·93	2·82	.....	80·2	1,160	0·0123	230	Dl.
Br. ...	172	12·40	4·13	Not	Taken	89·0	——	0·0116	.....	Dm.
Ca. ...	162	10·60	8·06	2·54	.....	82·1	1,020	0·0122	225	Dl.
Fi. ...	169	10·85	7·17	3·68	.....	99 5	1,220	0·0124	225	Dm.
Os. ...	164	11·90	9·00	2·90	.....	84·7	1,130	0·0121	235	Dl.
S. D.	160	13·40	10·75	2·65	2·30	71·0	1,070	0·0124	275	Ts.
Average		11·29	...	...	.....	85·1	1,069 (39·1 tons per sq. in.)	0·01221	.....	.....
Object of Trial:—To Machine Maximum Area of Surface.										
A. W.	182	12·09	7·05	5·85	.... .	66·2	2,920	0·02140	215	Dl.
Bu. ...	177	11·35	6·90	4·45	.. ...	62·0	2,370	0·02130	190	,,
Br. ...	185	11·90	6·75	5·15	.....	61·5	2,760	0·01890	215	,,
Ca. ...	173	13·70	7·95	5·75	.....	72·0	2,640	0·01575	205	,,
Fi. ...	179	10·50	5·66	4·84	...	64·0	2,500	0·02280	190	,,
Os. ...	175	11·80	8·00	3·80	.....	58·2	2,160	0·02370	235	Ts.
S. D.	186	11·70	6·90	4·80	.....	60·9	2,600	0·02140	210	Dl.
Average		11·98	.....	... ..	.....	63·5	2,564 (55·1 tons per sq. in.)	0·02075	.....	... .
Object of Trial:—To remove Maximum Weight per minute.										
A. W.	183	14·70	6·37	8·33	.....	55·50	4,959	0·0459	190	Dl.
Bu. ...	178	13·20	7·90	5·30	.....	49·00	3,570	0·0474	220	Ts.
Br. ..	184	15·00	6·66	8·34	.....	53·00	5,200	0·0420	185	Dl.
Ca. ...	174	11·90	6·75	5·15	.....	43·80	3,880	0·0460	185	Ts.
Fi. ...	180	13·70	4·95	8·75	.....	53·20	5,420	0·0462	240	,,
Os. ...	176	12·20	6·85	5·35	.....	48·50	3,650	0·0460	205	,,
S. D.	187	12·27	5·71	6·56	.....	52·25	4,150	0·0455	200	,,
Average		13·28	.....	.....	.....	50·75	4,403 (43·5 tons per sq. in.)	0·0456	.....	.....

TABLE XVII.—MEDIUM CAST IRON.

1	2	3	4	5	6	7	8	9	10	11
Tool Steel Maker.	Number of Trial.	Horse Power. Electrically Measured. Gross.	Lost.	Net.	Corrected Net.	Average Cutting Speed.	Cutting Force on Point of Tool.	Area of Cut.	Mean Revs. of Motor.	Gear and Cone Step in use.
Object of Trial :—To obtain Maximum Cutting Speed.										
						Ft. per min	Lbs.	Sq. in.	P. min.	
A. W. ...	52	10·10	8·5	1·65	1·365	50·70	890	0·00381	242	Ts.
Bu.	42	8·81	7·58	1·23	0·955	51·80	608	0·00350	230	,,
Br.	50	7·91	5·71	2·00	.. .	62·00	1,064	0·00290	205	Dl.
Ca.	54	9·05	7·32	1·83	.....	68·50	882	0·00350	230	,,
Fi.	46	10·64	9·22	1·42	1·410	56·88	815	0·00393	265	Ts.
Os.	44	9·50	.....	...	... ..	69·00	.....	0·00313	218	Dl.
S. D. ...	48	12·40	10·23	2·17	1·730	59·70	956	0·00331	275	Ts.
Average		9·77	.....	.....	.....	59·8	869 (112 tons per sq. in.)	0·00347	.....	.....
Object of Trial :—To obtain Maximum Cutting Speed.										
A. W. ...	53	11·46	8·32	3·14	.....	40·30	2,570	0·0099	264	Tm.
Bu.	43	9·38	7·12	2·26	.....	49·00	1,520	0·0115	220	Ts.
Br.	51	8·90	7·37	1·53	.....	48·80	1,034	0·0110	214	,,
Ca.	55	10·90	8·00	2·89	.....	50·20	1,870	0·0109	235	,,
Fi.	47	9·19	6·65	2·54	.....	44·24	1,895	0·0105	200	Tl.
Os.	45	10·75	8·73	2·02	.....	49·80	1,340	0·0097	226	Ts.
S. D. ...	49	11·62	8·50	3·13	.....	51·20	2,022	0·0108	240	,,
Average		10·31	.....	.....	.....	47·7	1,750 (73·7 tons per sq. in.)	0·0106	.....	.....
Object of Trial :—To Machine Maximum Area of Surface.										
A. W.	58	10·1	6·55	3·55	.....	33·10	3,530	0·0227	227	Tm.
Bu.	64	11·76	8·44	3·32	.....	50·00	2,190	0·0221	256	Ts.
Br.	60	9·65	6·11	3·54	.....	30·30	3,855	0·0203	215	Tm.
Ca.	56	11·95	8·34	3·61	.....	31·90	3,730	0·0175	280	Tl.
Fi.	62	12·55	7·90	4·65	3·975	34·40	3,800	0·0219	235	Tm.
Os.	68	13·15	8·95	4.20	3·940	34·40	3,765	0·0223	260	,,
S. D. ...	66	11·90	8·30	3·60	.....	36·60	3,245	0·0219	270	,,
Average		11·58	.....	.....	.....	35·80	3,445 (72·5 tons per sq. in.)	0·0213	.....	.....
Object of Trial :—To Remove Maximum Weight per minute.										
A. W. ...	59	15·19	8·08	7·11	.....	27·70	8,470	0·0373	260	Tl.
Bu.	65	11·59	7·27	4·32	.....	24·35	5,860	0·0446	240	,,
Br.	61	13·54	7·18	6·36	.....	25·20	8,330	0·0351	235	,,
Ca.	57	12·50	7·38	5·12	.....	25·60	6,600	0·0401	240	,,
Fi.	63	10·62	6·48	4·14	.....	22·00	6,210	0·0440	206	,,
Os.	69	14·10	8·59	5·51	.....	25·10	7,240	0·0407	257	,,
S. D. ...	67	13·17	7·60	5·57	.....	25·40	7,240	0·0377	258	Tm.
Average		12·96	.....	.....	.....	25·00	7,136 (80 tons per sq. in.)	0·0399	.....	.....

TABLE XVIII.—HARD CAST IRON.

1	2	3	4	5	6	7	8	9	10	11
Tool Steel Maker.	Number of Trial.	Horse Power Electrically Measured. Gross.	Lost.	Net.	Corrected Net.	Average Cutting Speed.	Cutting Force on Point of Tool.	Area of Cut.	Mean Revs. of Motor.	Gear and Cone Step in use.
Object of Trial:—To obtain Maximum Cutting Speed.										
						Ft. per min	Lbs.	Sq. in.	P. min.	
A. W. ...	107	11·67	9·88	1·79	1·080	36·4	980	0·00369	240	Ts.
Bu.	190	9·39	8·20	1·19	0·99	31·1	1,050	0·00398	250	Dl.
Br.	113	12·96	10·64	2·30	0·825	38·5	715	0·00375	270	Ts.
Ca.	109	11·15	9·65	1·50	0·525	38·6	450	0·00359	255	,,
Fi.	117	11·36	9·17	2·19	1·190	36·0	1,085	0·00390	260	,,
Os.	121	11·90	9·70	2·20	1·710	37·5	1,500	0·00343	280	,,
S. D. ...	111	10·25	8·5	1·75	1·15	38·4	985	0·00378	250	,,
Average		11·24	.....	.....	.....	36·65	966·4 115 tons per sq. in.	0·00374	.....	.....
Object of Trial:—To obtain Maximum Cutting Speed.										
A. W. ...	108	9·32	7·83	1·49	.....	30·3	1,620	0·01173	210	Ts.
Bu	191	8·15	6·73	1·42	.....	26·7	1,750	0·01048	210	Dl.
Br.	114	10·20	7·72	2·48	.....	30·5	2,680	0·01010	220	Ts.
Ca.	110	9·42	8·14	1·28	.....	31·9	1,324	0·01173	242	,,
Fi.	120	9·65	8·20	1·45	.....	31·8	1,500	0·01155	240	,,
Os.	122	9·50	7·64	1·86	.....	29·5	2,080	0·01061	230	,,
S. D. ...	112	9·00	6·63	2·37	.....	30·1	2,600	0·01119	210	,,
Average		9·32	.....	.....	... ..	30·1	1,936 78 tons per sq. in.	0·01105	.....	.....
Object of Trial:—To Machine Maximum Area of Surface.										
A. W. ...	125	11·33	7·98	3·35	2·55	21·00	4,010	0·02345	240	Tm.
Bu.	189	10·20	7·68	2·52	.....	20·80	3,998	0·01725	225	Ts.
Br.	115	9·50	6·75	2·75	2·02	20·20	3,300	0·02155	205	Tm.
Ca.	129	10·05	7·10	2·95	.....	25·00	3.930	0·02025	230	Ts.
Fi.	118	11·20	8·66	2·54	.....	24·70	3,393	0·02112	260	Tm.
Os.	124	9·52	7·52	2·00	.....	20·10	3,290	0·02175	234	,,
S. D. ...	127	10·22	7·22	3·00	.....	24·75	4,000	0·01912	210	Ts.
Average		10·29	.....	... ..	... ..	22·36	3,703 80 tons per sq. in.	0·02064	.....	.....
Object of Trial:—To Remove Maximum Weight per minute.										
A. W. ...	126	11·10	7·61	3·49	.....	18·00	5,450	0·0457	232	Tm.
Bu.	188	10·50	6·74	3·76	.....	18·45	6,730	0·0363	180	Ts.
Br.	116	8·25	5·92	2·33	.....	17·20	4,480	0·0448	190	Tm.
Ca.	130	12·15	8·85	3·30	.....	18·10	5,700	0·0426	280	,,
Fi.	119	11·60	8·60	3·00	.....	22·00	4,500	0·0459	260	,,
Os.	123	.....	.....	.....	.....	.....	.....	.....	.....	.....
S. D. ...	128	12·50	9·06	3·44	.....	19·50	5,800	0·0441	270	Ts.
Average		11·02	.....	.....	.....	19·00	5,443 56·4 tons per sq. in.	0·0432	.....	.....

NOTES ON LOCOMOTIVE & RAILWAY ENGINEERING

By CHARLES S. LAKE.

The Suburban Traffic Problem.

THIS all-important subject is receiving most careful attention on the part of railway authorities at the present time. The matter has now reached a stage at which it resolves itself principally into a question of the superiority, or otherwise, of electricity over steam for the purposes of traction on suburban lines.

It goes without saying that the railway companies would prefer to continue in the use of steam locomotives and the present methods of haulage, if possible, rather than resort to any scheme involving large outlays of capital, such as the conversion to electrical propulsion on an extended scale would necessitate.

There is no difficulty whatever about providing steam locomotives capable of dealing satisfactorily with any train which can be accommodated at the existing platforms, so far as hauling capacity alone is concerned; and that is not urged as a reason why present methods should be discontinued. The point is, whether or not it is possible to design locomotives which will give the necessary acceleration, and that without concentrating too much weight on a limited section of the permanent way.

In the London district, for instance, vast numbers of passengers have to be transported from the outlying suburbs to the terminal stations of the railway companies, and *vice versâ*, during stated hours on each day, and, as it is not practicable to extend the length of the trains, owing to lack of platform accommodation, the next best thing to do is to despatch a greater number of trains within a given period. This can only be brought about by securing a more rapid circulation of the trains, and to ensure this it is imperative that as little time as possible should be lost in "getting away" from the stations.

It seems to be generally accepted that a speed of 30 mls. per hour within 30 secs. of starting away from a state of rest is sufficient for the attainment of the desired result. To overcome the initial resistance at starting, and obtain this speed in the given time, it is advisable to employ engines having four or more pairs of coupled wheels of small diameter for the heaviest trains.

The wheel-base is restricted on account of curves and like considerations, and thus the tendency is to throw a greater strain upon the permanent way than much of the suburban track is in a condition at present to withstand. With the electric locomotive rapid acceleration is a strong point, and it is not attended by the objections which apply in the case of the steam locomotive; but, for various reasons, it will be greatly to the advantage of the railway companies if the difficulties can be overcome without abandoning the use of steam.

The ten-coupled "tank" locomotive designed by Mr. Holden for the suburban traffic of the Great Eastern Railway gave evidence of a determined effort to solve this problem without resorting to electricity, but as the engine is not to be placed in service on the class of traffic for which it was specifically designed, it is impossible, at the time of writing, to speak of its performances under actual working conditions. On the other hand, the eight-coupled "radial" tank engine which Mr. Ivatt has introduced upon the Great Northern is a pronounced success, and has proved in working to be in possession of capabilities far in advance of anything required of it at present. This is all the more satisfactory when it is understood that the engine is in no sense a special design, but may be described as one of the Company's standard eight-coupled goods engines with side tanks, bunker, and radial wheels added.

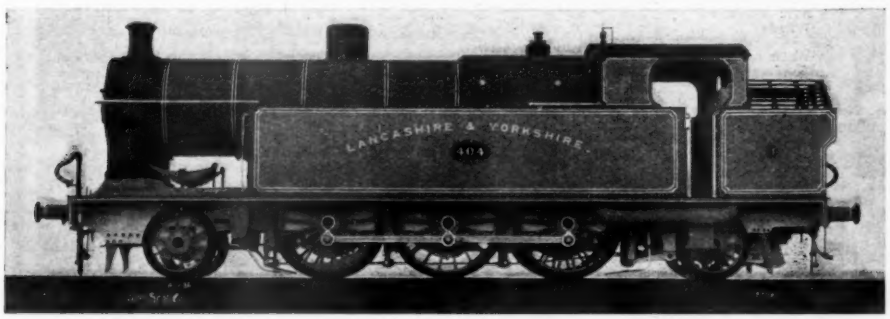
It is evident that we are at present only upon the threshold of an experimental era in this connection, and many expedients remain to be tried before the disappearance of the steam locomotive as a necessary factor in the conduct of suburban traffic is an accomplished fact.

A Lancashire and Yorkshire Solution of the Problem.

The views of Mr. H. A. Hoy, Chief Mechanical Engineer of the Lancashire & Yorkshire Railway, upon any subject relating to railway traction are worthy of everyone's attention, and his opinion as to what is necessary in the design of a locomotive intended for dealing with heavy suburban traffic may be gathered at a glance at the accompanying illustration and the particulars of the engine which it represents.

The design is a remarkable one, embodying as it does many features which are quite new to British practice. The Great Western Railway Company have recently placed in service a somewhat similar locomotive but of lesser proportions. The wheel arrangement in both cases is the same, but the Great Western engine is provided with outside cylinders and a smaller boiler than that which Mr. Hoy has designed; indeed, the same class of boiler is used with these new tank engines illustrated as with the large 4–4–2 express locomotives of the 1400 series, and also the eight-coupled goods engines on the same railway. The Lancashire and Yorkshire Company have an immense local traffic of an exceedingly heavy character, and on frequent occasions they are called upon to deal with abnormal train loads, notably during the football season, and there is also the heavy excursion traffic to Blackpool, Southport, etc., in the summer months.

The gradients in many districts are severe and the booked speeds considerable, but the distances are comparatively short in every case, therefore a powerful class of tank engine amounts to a necessity, and it is to be wondered at that the expedient has not been tried before. As will be seen, the engine is of the 2-6-2-type, with radial leading and trailing wheels. The side tanks appear to be somewhat shallow, but this effect is really due to the immense size of the boiler and the height at which its axis is pitched above the rail level. The boiler mountings at once attract the eye of those who are conversant with L. & Y. Railway standard practice in this respect. The chimney is of a new pattern, and the dome is practically flat-topped. This gives a greater internal area, but it cannot be said to improve the appearance of the engine. The safety-valves are also of a new design. The studious attention of the reader is directed to the following dimensions, which are in many respects remarkable for the type of locomotive under notice. The writer is indebted to Mr. Hoy, both for the photo and dimensions.



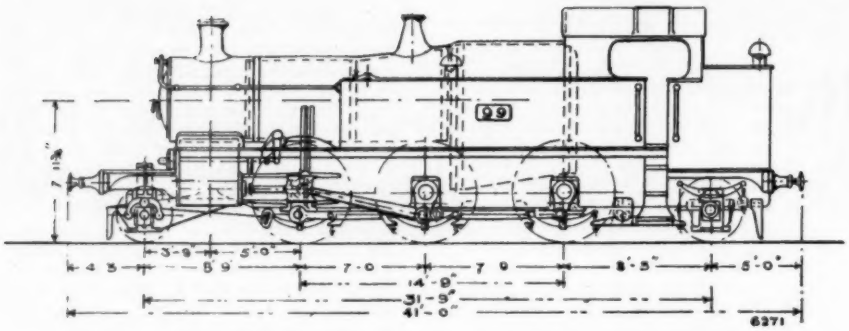
NEW 2-6-2 TYPE LOCOMOTIVE, LANCASHIRE AND YORKSHIRE RAILWAY, FOR HEAVY SUBURBAN TRAFFIC.

Cylinders	...	...	...19 ins. dia. by 26 ins. stroke.
Wheels (coupled)	...	...	... 5 ft. 8 ins. dia.
,, (radial)	...	...	... 3 ft. 7⅛ ins. dia.
Heating surface—tubes	...		1877·0 sq. ft.
,, ,, firebox	...		161·64 sq. ft.
			2038·64 sq. ft.
Grate area	...	...	26·05 sq. ft.
Water	...	...	2,000 gals.
Coal	...	...	3¾ tons
Total wheel base	...	...	27 ft. 7 ins.

Weight in working order.

	Tons	cwts.	qrs.
Front radial wheels	10	12	2
Front coupled wheels	17	19	1
Intermediate coupled wheels	17	4	1
Trailing coupled wheels	17	4	0
Hind radial wheels	14	10	1
Total ...	77	10	1

The engine is fitted with water scoop arrangement, which picks up water when travelling in either direction; also with double-ported slide valves.



DETAILS OF NEW 2-6-2 TYPE LOCOMOTIVE, GREAT WESTERN RAILWAY.

Cylinders	diam. 18 ins., stroke 30 ins., steam ports 31½ ins. by 1¾ in., exhaust 31½ ins. by 4¼ ins.
Boiler	barrel 11 ft. 0 in., diam. outs. 5 ft. 0½ in. and 4 ft. 5⅛ ins.
Firebox ... outs.	7 ft. 0 in. by { 5 ft. 3 ins. / 4 ft. 0 in. } ; ins. 6 ft. 2 5/16 ins. by { 4 ft. 3⅛ ins. / 3 ft. 2⅝ ins. } ; height 6 ft. 0 7/16 in. and 5 ft. 0 7/16 in.
Tubes	Number 289, diam. 1⅝ in., length 11 ft. 4 1/16 ins.
Heating surface	tubes 1396·58 sq. ft., firebox 121·31 sq. ft., total 1517·89 sq. ft.
Area of firegrate	20·35 sq. ft.
Wheels	pony truck 3 ft. 2 ins., intermediate 5 ft. 8 ins., driving 5 ft. 8 ins., intermediate 5 ft. 8 ins., radial truck 3 ft. 8 ins.
Water capacity of tank	1500 gallons.
Working pressure	195 lbs.
Tractive force	21,086 lbs.

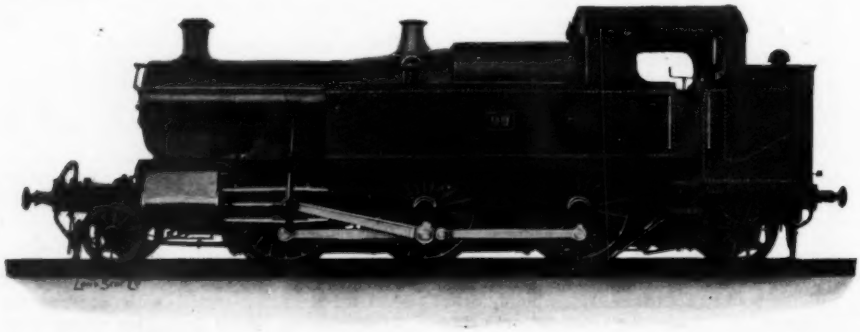
Weights on Axles.

	P. Truck. Tons	cwt.	Intermediate. Tons	cwt.	Driving. Tons	cwt.	Intermediate. Tons	cwt.	R. Truck. Tons	cwt.		Total. Tons	cwt.
Full	7	0	16	13	17	0	17	0	14	10	=	72	3

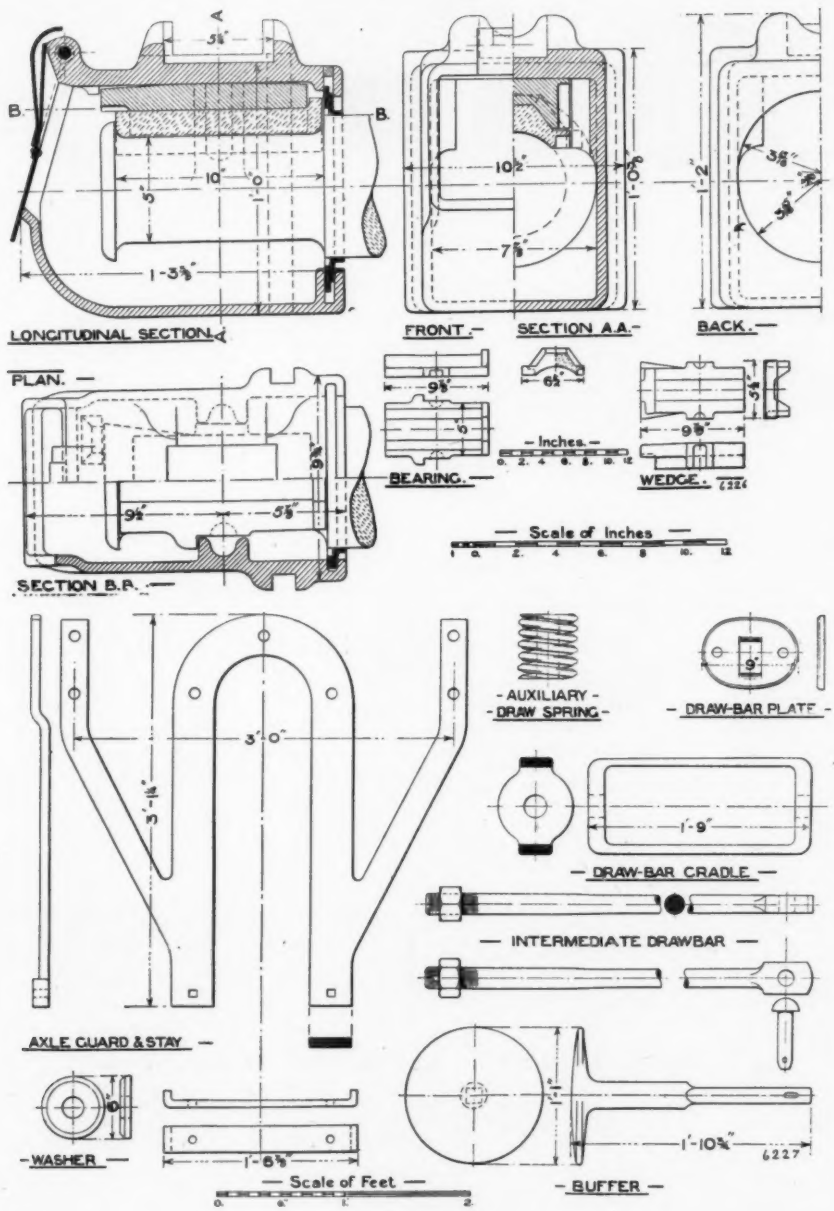
The Contemporary Design on the Great Western Railway.

The Great Western engine, which is also illustrated, has a decidedly American appearance, and many interesting features are incorporated in the design. Principal among these is the large end of the connecting-rod, which is circular, instead of being of the usual rectangular pattern. The boiler is of the coned-ring type already referred to in these notes.

The principal dimensions of the engine appear with the diagram, for which, in addition to the photograph, the writer is indebted to Mr. G. J. Churchward, the Great Western Company's Locomotive Superintendent.



NEW 2-6-2 TYPE LOCOMOTIVE FOR HEAVY SUBURBAN TRAFFIC, GREAT WESTERN RAILWAY.



[PRIVATE OWNERS' 20-TON WAGON: AXLE-BOX AND IRONWORK DETAILS.

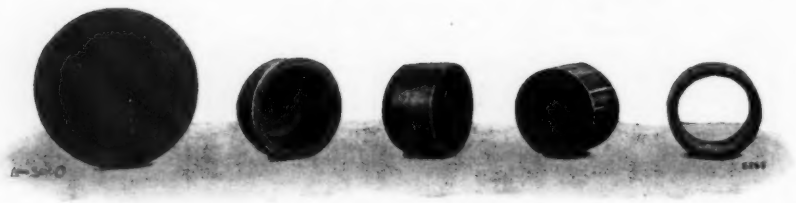


PHOTO. SHOWING THE DIFFERENT STAGES OF MANUFACTURE OF STEEL FERRULES FOR THE TUBES OF A LOCOMOTIVE BOILER, LONDON AND NORTH-WESTERN RAILWAY.

Private Owners' 20-ton Wagons.

Further details are shown herewith of the standards to be followed in the construction of these wagons. Clause 14 of the specification issued by the Railway Clearing House Committee sets forth that oil axle-boxes are to be used. They are to be cast of good strong iron or steel, or may be made of pressed steel, are to have brass or bronze bearings well fitted in, and must be to an approved design. The top of the box is to be so formed that the bearing-spring will bed into it 2 ins. An efficient shield is to be put in the back of the box to keep out dust.

The drawings which accompany the specification show on a separate sheet an alternate design for axle-boxes differing in some matters of detail from that herewith reproduced.

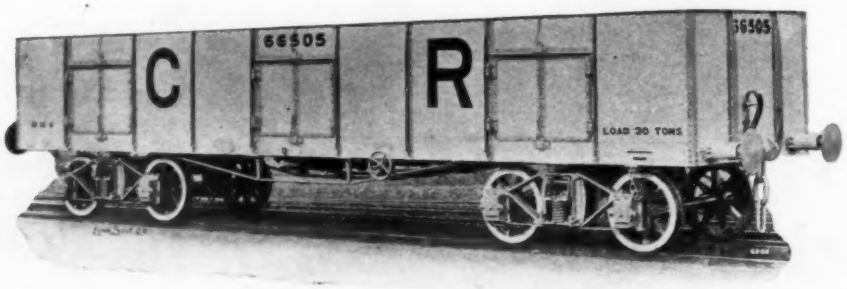
Drawing No. 49 bears the title "Ironwork Details," and shows the design of pedestals, auxiliary draw-springs, buffers, and draw-bar details generally. The draw-gear throughout is to be made of the best cable-iron or mild weldable steel of Government chain-proof quality, and to be continuous and elastic and of the dimensions shown on the drawings.

The body of the axle-guards to be made of 4-in. by $\frac{7}{8}$-in. iron, and the wings of $2\frac{1}{2}$-in. by $\frac{7}{8}$-in.; the bottom stay, or bridle, to be $2\frac{1}{2}$ ins. by $\frac{5}{8}$ in. The holes for the rivets are to be $\frac{13}{16}$ in. in diameter, and must be drilled. Each axle-guard must be securely attached to the frame by seven rivets, three of which are to be in the crown and two in each wing.

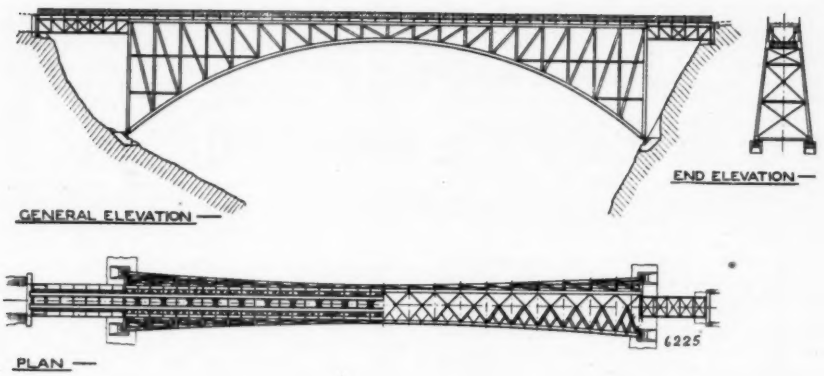
Economy and Ingenuity at Crewe.

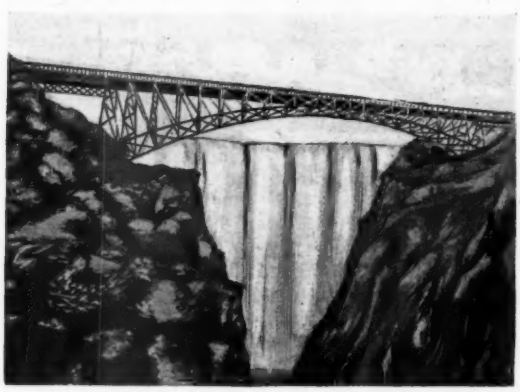
During a visit to Crewe Works in the early part of 1903 the writer was shown, among other interesting appliances, a special tool which Mr. Webb had designed for producing the ferrules which are used in the ends of locomotive boiler tubes, and at a later stage was enabled to witness the process of manufacturing the ferrules in a series of operations which were at once interesting and instructive.

First a long flat bar, about $3\frac{1}{4}$ ins. in width and No. 9 s.w.g. in thickness, is passed along under the die of a punching machine, which rapidly punches out as many discs 3 ins. diameter as the length of the bar will permit.



30-TON MINERAL WAGON, CONSTRUCTED FOR THE CALEDONIAN RAILWAY BY MESSRS HURST, NELSON AND CO., LTD., MOTHERWELL.





BRIDGE TO CARRY THE CAPE TO CAIRO RAILWAY OVER THE ZAMBESI RIVER AT VICTORIA FALLS.

These fall into a box below and are conveyed to another machine, where each disc in succession is placed in the orifice of a bell-mouthed die, through which it is forced by the descent of the male die and reaches the receptacle beneath in the form of a cup. After this it is annealed and pickled, and is then pressed through another die, recupped and straightened up, and is then again annealed and pickled.

The next die through which it passes is specially formed so as to produce ribs or projections on the outer surface of the cup, and in this passage also a certain amount of taper is imparted to the semi-completed article.

The remaining operations consist of punching a hole through the end of the cup, thus forming it into a ferrule proper, and finally it is once more annealed, and is then ready to be sent into the erecting shop for immediate use if necessary.

The ribs on these ferrules have proved very effective in a "hold fast" capacity, as the tendency is for them to cut into the inner surface of the tube when driven into position, and thus a great deal of annoyance and inconvenience is avoided which might occur through ferrules working loose.

The various stages of manufacture are clearly shown in the accompanying reproduction. The operations are five in number, and the state of the article after the completion of each is shown as described, counting from left to right.

Thirty-ton Mineral Wagons on the Caledonian Railway.

In last month's Notes one of the 30-ton wagons employed upon the Great Northern Railway was illustrated, and the accompanying reproduction shows a similar type of wagon, of the same carrying capacity, in use upon the Caledonian Railway Co., and constructed by Messrs. Hurst, Nelson & Co., Ltd., of Motherwell.

The writer is indebted to Mr. J. F. McIntosh, Locomotive Superintendent to the last-named Company, who, in sending the photographs, kindly included the following particulars relating to the wagons :—

Body length	35 ft. 0 in.
,, width	8 ft. 0 in.
,, depth	4 ft. 4 ins.
,, height from rail to top of side	8 ft. 1½ ins.
,, ,, ,, floor	3 ft. 9 ins.
Length over buffers	38 ft. 0 in.
Wheel base of bogies	5 ft. 6 ins.
,, ,, total	29 ft. 6 ins.
Tare	13 tons 7 cwts.
Cubic capacity	1,200 cub. ft.
Wheels	3 ft. 9 ins. diam.
Journals	10 ins. by 5 ins.

A Remarkable Railway Bridge.

Among the many important contracts which have been undertaken during recent years by the Cleveland Bridge and Engineering Co., Ltd., of Darlington, one upon which they are at present engaged ranks among the foremost. That great scheme—the Cape to Cairo Railway—the masterpiece of the creative mind of the late Mr. Cecil Rhodes, is being pushed forward as rapidly as the difficulties entailed by the circumstances will permit, and a notable link in the gigantic enterprise when completed will be the bridge carrying the track over the Zambesi River at a point distant only a few hundred yards below the celebrated Victoria Falls, of which passengers by the railway will obtain an unparalleled view.

The railway is being advanced from Bulawayo, through North-Western Rhodesia, and is at present completed up to within 60 miles of the River Zambesi, which will be spanned by the bridge. The bridge, which will carry two lines of railway, has one span 600 ft. in length, and other dimensions as shown upon the accompanying drawing.

The engineers are Sir Douglas Fox and Sir Charles Metcalfe.

It will cross the river 400 ft. above water level. No staging will be used during erection on account of the great height, and the bridge will be built out from each side on the cantilever principle. A transporter on the Brothers' system, capable of dealing with loads up to 10 tons, will be used for carrying materials, etc. Catch nets will be used to ensure the safety of the men who are engaged upon the hazardous work of erection. The total weight of steelwork involved in construction of the bridge is 1,600 tons. The work was well in hand in the Cleveland Company's yard at the time of writing, and the first consignment was due to leave this country for site of erection at the end of the month.

The work of erection will be carried out under the supervision of Mons. Georges Imbault acting on behalf of the builders. It may be said that the Cleveland Bridge and Engineering Co., Ltd., are now in the front rank among modern bridge builders, and their works, which were established in 1877, are equipped with all the latest and most up-to-date appliances necessary for handling the heaviest class of structural work on scientific and expeditious lines.

In 1902 they secured the largest bridge contract let in Great Britain since the completion of the Forth Bridge. This was the contract for the North Eastern Railway Company's new high-level bridge to carry their main line, consisting of four tracks, over the River Tyne at Newcastle. This included the foundations, masonry piers, and brickwork, as well as the iron and steelwork involved; the estimated value of the work being £500,000 sterling.

MARINE ENGINEERING & SHIPBUILDING NOTES

North-East Coast.

AFTER a period of considerable suspense the labour troubles in North-East Coast engineering circles have been settled, or—to put the case more fairly—further consideration of the proposed reductions has been postponed for another six months, on the part of the employers.

At a mass meeting, held in Newcastle-on-Tyne on February 6th, of the Amalgamated Society of Engineers, the Machine Makers, and Steam Engine Makers, the proposed reductions of 2*s.* on wages of over 30*s.* per week, 1*s.* 6*d.* on wages between 30*s.* and 25*s.* per week and 1*s.* on wages of 25*s.* a week and under, together with a 5-per-cent. reduction on all piece wages, were considered and unanimously rejected. However, about the beginning of February a marked improvement in trade was apparent, so much so that the masters determined not to press the matter at present but to wait for events to prove whether the improvement is of a permanent or merely transitory character. The withdrawal affects the Tyne, Wear, Tees and Hartlepools only. At the time of writing the action of the employers in the other great engineering and shipbuilding centres had not been determined. We trust that a similar course may be pursued, and thus prevent any serious dislocation in the engineering trade.

Since writing the notes for this column in last month's issue, events have moved with great rapidity, and the attention of everyone is directed towards the Far East, almost to the exclusion of other topics of pressing importance. The effect of the naval engagements which have taken place will without doubt solve a great many of the problems which have hitherto been left to the imagination for solution, and prove the utility or otherwise of many of the ingenious mechanical contrivances which have been a marked feature of warship equipment within the last twenty years. However deplorable the fact that recourse to arms has been deemed necessary by the Powers at present engaged in conflict, there is little doubt that out of the evil beneficial results will finally accrue, and that the lessons learnt will act as a healthy tonic to national life.

National sentiment in this country is naturally on the side of the Asiatic, and, we venture to think, rightly so. The nation at large has always held out the hand of friendship to this plucky little country, and the North-East Coast in particular will watch the trend of affairs with the deepest interest and anxiety, for it was on the banks of the Tyne, in 1885, that two of the first modern warships, the *Naniwa* and the *Takachiho*, were turned out, and since then the fleet has been augmented from time to time by some of the finest specimens of naval architecture and marine engineering afloat.

The *Yashima* and *Hatsuse*, both built at Elswick, rank among the most powerful battleships afloat. The latter, and more recent, vessel has a total displacement of about 15,000 tons and a speed of over 19 knots.

The first-class armoured cruisers, *Asama*, *Tokiwa*, *Idzumo*, and *Iwate*, which, together with the battleships, have only made their advent since the Chino-Japanese war, are types of vessels which owe their inception to the banks of the Tyne. They combine with practically all the powers of offence and defence of a modern first-class battleship the speed of a first-class cruiser, and are in every way most formidable opponents for any foe to tackle. They can steam between 21 and 22 knots per hour. Among a number of smaller vessels which have already shown exceptional powers of attack, the *Yoshino* will probably be remembered as one which did excellent service during the Chino-Japanese War. With these vessels, and many others such as these, together with a

personnel already famed for discipline and devotion to duty, the conflict will, from the naval constructors' point of view, be an interesting one and one from which many valuable lessons may be learned.

Messrs. Sir W. G. Armstrong-Whitworth & Co., of Elswick, and Messrs. Vickers, Sons & Maxim, of Barrow, have each received orders to proceed with the construction of a first-class battleship for the Japanese Navy. The contract time is stated to be 18 months, which, if fulfilled, will establish a record in the annals of battleship building. The new vessels are designed on similar lines to the *King Edward VII.*, but will have a heavier secondary armament and heavier armour. The main armament consists of four 12-in. B.L guns twin-mounted in barbettes. The armour protection will be similar to that introduced in the *Nukasa*, which was built by Vickers, Sons & Maxim for Japan, and which has since been adopted in all ships designed for the British Navy. These vessels are the most powerful fighting machines yet ordered, and when finished will have cost about £1,250,000 each.

Tempted, doubtless by low prices, a number of shipowners have placed orders on the Tyne, Wear, and Tees within the last month or six weeks, but none are of a very exceptional character. A fair amount of repair work is being carried out, though on the Tees, at present, this industry is quiet on account of the graving dock being closed for overhauling. Lack of dry-dock accommodation has been a great drawback to the Tees ship-repairing industry in the past. It is expected that, with the increased facilities afforded by the alterations at present being carried out, this industry may be in a better position to undertake larger contracts in the future than have hitherto been possible. The pontoon dock which was recently installed by Messrs. S. P. Austin, of Sunderland, in connection with their shipbuilding establishment, has been busily employed since being put into position. The most important contract recently carried out were some extensive repairs to the s.s. *Canada Cape*, a new vessel which, during her passage from the Tyne to the Wear to receive her propelling machinery, sustained considerable damage while entering the harbour.

After repeated representations made to the Board of Trade by shipowners of this country regarding the tonnage measurement of foreign ships entering British ports, it is gratfying to note that the Board has asked the Foreign Office to notify the Governments of France and Spain (whose tonnage regulations differ materially from ours) that, after April 1st next, all vessels entering and trading in British ports will be subject to remeasurement, unless they are already provided with certificates of British tonnage. It seems almost inconceivable that British shipping has had to labour under such an injustice for so long, and yet this is only one example of many which the British shipowner has to contend with in his endeavours to obtain and hold a share in the world's carrying trade. We hope that the time may not be far distant when the maximum load-line may also be enforced on foreign vessels trading in our waters. It does appear preposterous that any foreigner having bought a vessel from British owners can, after having placed her under a foreign flag and measured according to the regulations of her new nationality, return with her to British waters and be permitted, on account of her new tonnage measurement, to pay less harbour dues, dock dues, etc., and, further, be allowed to load her to a greater draught than would be permitted by the Board of Trade regulations had she flown the red ensign.

The artificial system of encouraging shipping by granting subsidies is not wanted in this country, for with equitable taxation of British and foreign tonnage and a similar basis for payment of harbour and dock dues, so as to place all vessels, irrespective of nationality, on the same footing, together with some other much desired modifications in the shipping laws, we would not fear for a moment that our position as premier in the world's carrying trade will ever be wrested from us. H. B. D.

Scotland.

Little or no improvement can be recorded in the position of matters on the Clyde. During January over 17,000 tons of new orders are returned as booked on the river, a figure which offers no prospect of a speedy return to busier times. Under the circumstances it will afford no surprise that the wages question is under discussion, and the problem of a reduction is being calmly faced by the men, who recognise the difficulties of the situation.

Amongst the launches of the month that of the county cruiser H.M.S. *Roxburgh* is the most notable. The vessel is the third of her class entrusted by the Admiralty to the London & Glasgow Engineering & Shipbuilding Company, Ltd., of Govan. The

following are the principal dimensions of the *Roxburgh:* Length between perpendiculars, 450ft.; breadth (moulded), 68ft. 6ins.; depth (moulded) to upper deck, 38 ft. 6 ins.; load-draft, mean, 24 ft. 9 ins. The i.h.p. is 21,000, and the new vessel will develop a speed of 22¼ knots per hr. The *Roxburgh*, which is similar to H.M.S. *Devonshire*, at present under construction at Chatham, has the hull subdivided into numerous watertight compartments, and a double bottom under the magazine and machinery spaces both fore and aft.

The armour belting is 6 ins. in thickness, and extends from the lower to the main deck for a distance of about 250 ft. The armament may be briefly summed up as follows: Two 7·5 breech-loading quick-firing guns mounted in barbettes, one in the forecastle and the other on the upper deck aft; ten 6-in. guns of similar type in casemates on the broadsides; two 12-pounder quick-firing guns, two Maxims, and two submerged broadside torpedo tubes. Specially hardened steel 6 ins. in thickness is employed in the casemates and barbettes.

The vessel is engined by two sets of triple-expansion engines, the diameters of the cylinders being 73½ ins., 65½ ins., and 41½ ins. respectively, with a stroke of 42 ins. Each cylinder is steam-jacketed. In the aft boiler-room cylindrical boilers will be fitted with forced-draught arrangements by Messrs. Howden & Co., whilst in the other three boiler-rooms Durr boilers are placed working up to 220 lbs. per sq. in., and built by the Fairfield Company.

Another launch of interest during the past month is that of the Asiatic Steam Navigation Company's screw passenger boat *Shahzada*, built by Messrs. Charles Connell & Co., Ltd., of Whiteinch. The boat, which has a length of 300 ft., a breadth of 40 ft. 7 ins., with a moulded depth of 24 ft. 9 ins., will carry 3,200 tons dead-weight, and is specially designed for service in hot climates.

The trial trips of the *Nirvana*, a large twin-screw steam yacht, designed by Messrs. G. L. Watson & Co., and built by Messrs D. & W. Henderson & Co., of Meadowside, for the Countess of Bearn, have realised the expectations formed of her, a mean speed of 15·08 knots being obtained on the double run between the Cloch and Cumbrae lights.

Each of the two sets of engines has four cylinders—18 ins., 29 ins., and two 32 ins. diameter, the stroke being 33 ins. One large cylindrical boiler, working at 200 lbs. per sq. in., operates both engines.

Amongst the launches of the past month may be noted the first of the three steamers for the frozen meat trade between the Argentine Republic and this country recently ordered by Messrs. H. & W. Nelson, Ltd., from Messrs. Russell & Co., of Port Glasgow.

The vessel has a carrying capacity of 7,250 tons on 25 ft., and is fitted up with Messrs. Haslam's refrigerating machinery. The *Highland Watch's* dimensions are—length, 390 ft.; breadth, 52 ft. 6 ins.; depth, 29 ft. 6 ins. (moulded). The engines are by Messrs. Rankin & Blackmore, of Greenock.

The growing importance of the turbine in connection with shipping is emphasised by the fact, whilst at the moment Messrs. Denny Bros., the well-known Dumbarton firm, alone hold licences for the manufacture on the Clyde of the Parsons type of turbine, several other firms in this neighbourhood are reported to have applied to the Parsons Steam Turbine Co. for similar permits. In this connection it is interesting to note that the Dumbarton firm have in hand at the moment no less than seven turbine steamers. It is anticipated that ere long several of the Clyde-side firms will be enabled to turn out the new motor.

The rapid growth of the turbine industry is being watched with keen interest by engineers and shipbuilders alike.

A Paper recently read before the Association of the Students of the Institution of Civil Engineers in Glasgow dealt with the caissons recently sunk by the Clyde Trustees at the Broomielaw to maintain the quay, which was constantly giving way.

The employment of compressed air in the operations was a complete success, the manufacture of the caissons and the sinking being carried out by the well-known firm of Sir William Arrol & Co., Ltd., who are specialists at this class of work, and brought to bear their lengthened experience with cylinder sinking in such difficult structures to found as the Forth and Tay Bridges, and Redheugh and Barrow Viaducts.

No movement in the quay walls has occurred, it was stated, since their recent reconstruction with steel caissons.

The Clyde trustees, who are pushing on with their new dock at Clydebank, are about to apply to the Board of Trade for permission to deposit the excavations in Loch Long.

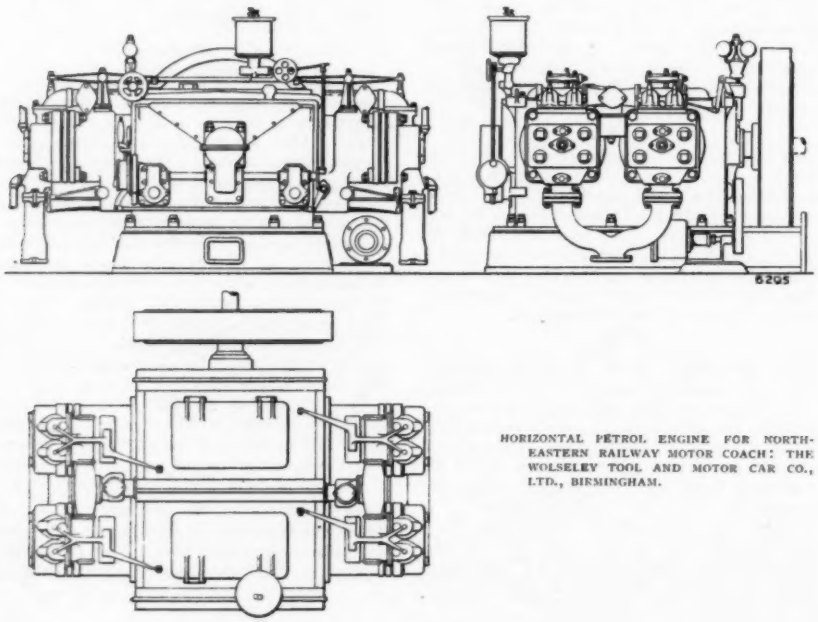
E. G. C.

NEW MACHINERY & APPLIANCES

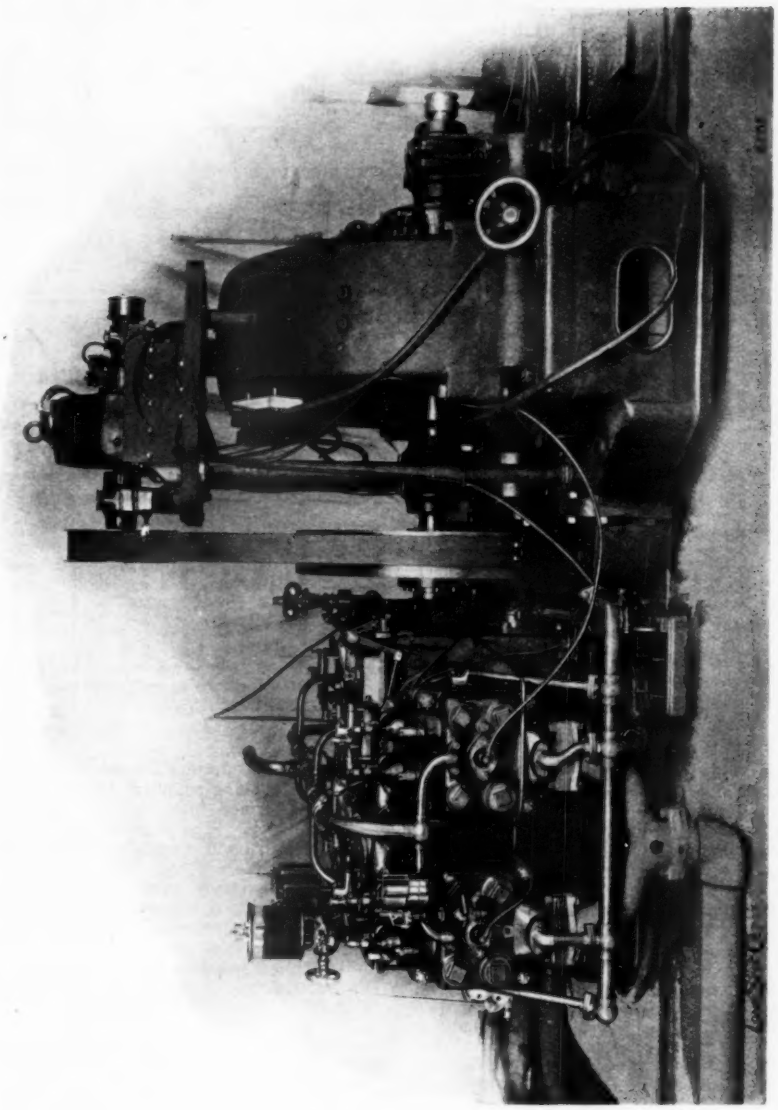
Motor-Driven Coach. North-Eastern Railway.

THE example recently set by the London and South-Western and Great Western Railway Companies in the adoption of self-contained motor coaches, has been speedily followed by the North-Eastern Railway, who have recently put into service a car of which a plan and elevation is shown herewith. An interesting departure, however, from the practice adopted by the Southern companies is marked by the introduction of this type, inasmuch as the steam power has been displaced in favour of petrol motors of the Wolseley type. The official trials went off without a hitch; speeds up to 40 miles per hour were attained, and the coach, which weighs 35 tons, climbed a bank of 1 in 95 without any trouble. The 60 miles non-stop test was accomplished in first-class style. The consumption worked out at one pint per b.h.p. hour. By the courtesy of the makers, The Wolseley Tool and Motor Car Co., Ltd., Adderley Park, Birmingham, we are enabled to furnish some details of, as well as to illustrate the motors themselves.

From the outline sketch it will be seen that the engine has four horizontal cylinders with a bore of $8\frac{1}{2}$ ins. and a stroke of 10 ins. These dimensions give—with a piston speed of 700 ft. per minute, and 420 revolutions



HORIZONTAL PETROL ENGINE FOR NORTH-EASTERN RAILWAY MOTOR COACH: THE WOLSELEY TOOL AND MOTOR CAR CO., LTD., BIRMINGHAM.



HORIZONTAL PETROL ENGINE FOR NORTH-EASTERN RAILWAY MOTOR COACH.

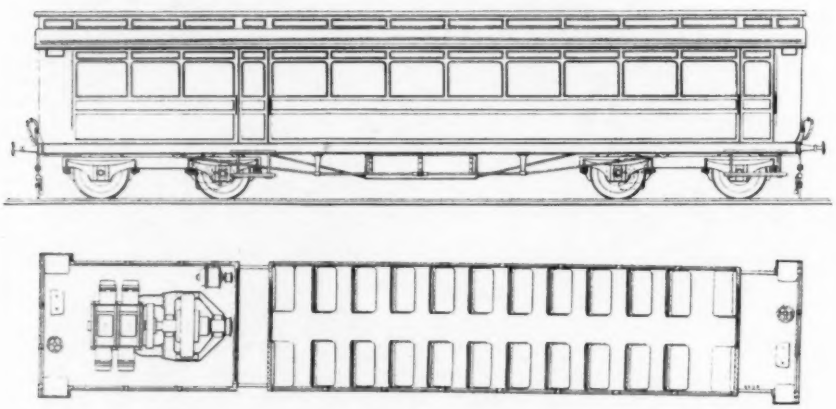
per minute respectively—94 i.h.p. or 81 b.h.p., and with an acceleration up to 800 ft. per minute piston speed and 480 revolutions, the engine gives 107 i.h.p. or 93 b.h.p. The cast-iron combustion chambers have ground conical joints between them and the liners—these in turn being jointed in the same way with the cast steel water jackets. The four cylinders are overhung on a stiffly constructed cast steel crank-chamber, with inspection covers on top and oil trough underneath—the crank chamber being entirely enclosed for ordinary working.

The engine in the North Eastern Railway coach is direct coupled to a 60-kilowatt Westinghouse electric generator. The current thus obtained is utilised on large car motors carried on the bogies.

The cylinders work in pairs on two crank pins at 180 degs. from each other, thus obtaining two impulses every revolution. This arrangement ensures a well-balanced engine. The cylinders and combustion chambers are cooled by water circulation, which is maintained by a rotary pump driven off the two-to-one countershaft by spiral gear. This countershaft drives the two valve-actuating camshafts by means of right- and left-hand spiral gear at either end.

There are two mushroom inlet and two mushroom exhaust valves to each cylinder, all positively actuated through rocking levers from camshafts carried in brackets on each side of the crank chamber.

The carburation and petrol feed is effected by an arrangement of one atomising jet and two mixture pipes to each cylinder. Constant petrol level is maintained by means of a float chamber and pressure feed through the medium of the exhaust.



PETROL AUTOMOTOR RAILWAY COACH FOR NORTH-EASTERN RAILWAY.

The charges are fired by electric ignition, the current being supplied by accumulators and transformed into high tension by an induction coil. The engine is governed on the throttle ; hand throttling is also provided for.

The approximate weight is 40 cwts., which could be reduced if it is necessary for the engine to be of the least possible weight per h.p.

The photograph shows the engine fixed up for testing purposes in the Wolseley shops.

NEW BOOKS & CATALOGUES.

BOOKS.

Automatic Surveying Instruments and their Practical Uses on Land and Water. By Thos. Ferguson, with an Introduction by E. Hammer, Ph.D. London: John Bale, Sons & Danielson, Ltd., 83-89, Great Titchfield Street, Oxford Street, W. Price 4*s.* net.

The Metallurgy of Steel. By F. W. Harbord, Assoc.R.S.M., F.I.C., with a section on the Mechanical Treatment of Steel by J. W. Hall, A.M.Inst.C.E. London: Charles Griffin & Co., Ltd., Exeter Street, Strand. Price 25*s.* net.

The Elements of Mining and Quarrying. By Sir C. Le Neve Foster, D.Sc., F.R.S., etc. London: Charles Griffin & Co., Ltd., Exeter Street, Strand. Price 7*s.* 6*d.* net.

Modern Engines and Power Generators. A Practical Work on Prime Movers and the Transmission of Power, Steam, Electric, Water, and Hot Air. By Rankin Kennedy, C.E. London: The Caxton Publishing Co., 84-86, Chancery Lane, W.C. Price 9*s.* net.

The Shipbuilding Industry of Germany.—Compiled and edited by G. Lehmann-Felskowski. London: Crosby Lockwood & Son, 7, Stationers' Hall Court, E.C. Price 10*s.* 6*d.* net.

Who's Who, 1904. London: A. & C. Black, Soho Square, W. Price 7*s.* 6*d.* net. *Who's Who Year-Book, 1904,* 1*s.* *The Englishwoman's Year-Book and Directory, 1904.* 2*s.* 6*d.* net.—This invaluable biographical dictionary has now assumed such ponderous proportions that it has been found necessary to issue the tables, which were such a popular feature of this publication, in separate form under the title of *Who's Who Year-Book.* Both books are absolutely indispensable to any up-to-date business man.

Modern Electric Practice. Edited by Magnus Maclean, M.A., D.Sc. London: The Gresham Publishing Co., 34, Southampton St., Strand. Price 9*s.* net.

Geometry for Technical Schools. By E. H. Sprague, A.M.Inst.C.E. London: Crosby, Lockwood & Son, 7, Stationers' Hall Court, Ludgate Hill.

The Cyanide Process of Gold Extraction. By James Park. Third Edition. London: Charles Griffin & Co., Ltd., Exeter St., Strand. Price 7*s.* 6*d.*

The Colliery Guardian Co., Ltd., 30, 31, Furnival Street, Holborn, E.C., have again issued their Colliery Manager's Pocket Book, Almanac and Diary for 1904, this being the 34th year of publication. It contains much valuable information, and no colliery manager should be without a copy.

Practical Electrician's Pocket Book and Diary for 1904, published by Messrs. S. Rentell & Co., Ltd., 36, Maiden Lane, W.C., has again made its appearance, for the sixth time, and shows a record of steady progress and improvement, keeping pace well with the most recent developments of electrical practice. Price 1*s.* cloth or 1*s.* 6*d.* leather, net.

CATALOGUES.

Chambers, Scott & Co., Motherwell, N.B. Pamphlet E. C. No. 1,904, dealing solely with their electric overhead travelling cranes with the following special features: alignment and adjustment assured, all bearings being bushed. No overhung wheels, all gearing placed between the cheeks. Number of gear reductions as small as possible.

Thos. Thompson & Co., 35, New Broad St., E.C., have issued a booklet giving a very clear description of their (new system) tachometer or speed indicator, and some of its applications, which is well worth perusal. Its most striking features are: none but rolling friction in the centrifugal mechanism, no oiling inside of dial box, hence constant sensitiveness; motion of pointer is rapid and quiet.

Mavor & Coulson, Ltd., 47, King Street, Mile End, Glasgow. A new and enlarged edition of the "Red" Book, setting out clearly the details of the "Pickquick Long Wall Coal Cutters" (Hurd's Patent), fitted with direct-current, three-phase, or compressed-air motors, all of which are the specialities of this firm. The brochure is well printed and illustrated.

British Prometheus Co., Ltd., Kingston-on-Thames.—A pamphlet describing and illus-

trating the Prometheus Electric Radiators and Heating Stoves. This system in all its features is claimed to be entirely different from any other, no wire coils or embedded wires being used, these being replaced by heating strips or elements consisting of metallic films deposited on mica sheets and enclosed in very thin metallic cases.

The Synchronome Co., 32–34, Clerkenwell Rd., E.C., have issued an interesting booklet dealing with "Electric Time Service," and explaining the "Synchronome System," by which an electrically-driven pendulum is used to control any number of dials.

Joseph Kaye & Sons, Ltd., Lock Works, Leeds.—Latest price-list of the well-known Patent Seamless Oil Cans, with details of recent patented improvements, viz., seamless spouts, valve and spout attachment, valve thumb-button, and a new serrated oil-can fitted with an automatic slide feed-hole. The latter type has been adopted by the Admiralty.

Robt. Ingham Clark & Co., Ltd, 6, St. Helen's Place, London, E.—This well-known firm of varnish manufacturers have adopted a decidedly novel form of catalogue. Taking advantage of the accidental circumstance that their works occupy the site of an ancient monastic establishment, they have prepared an interesting and well illustrated account of this abbey, which serves as an introduction to a description of its successor—the varnish works. The booklet is extremely well got up in antique style, and is bound in parchment.

The Linolite Co., 47, Victoria St., Westminster, S.W.—Illustrated booklet describing the system of electrical illumination recently introduced by this company. It is essentially a system of shop-window lighting, as it has for its object the diverting of the rays of light away from the spectator to the objects to be illuminated. This, of course, is economical, as no light is wasted by passing into the street.

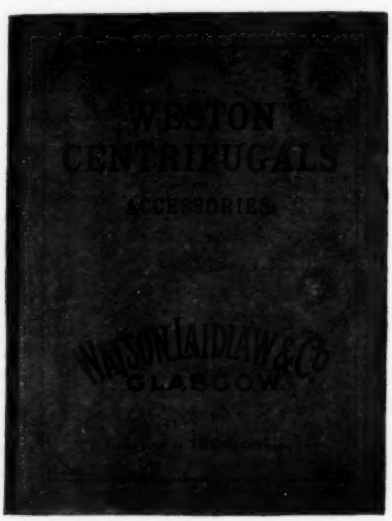
Columbian Fireproofing Co., Ltd., 37, King William Street, London, E.C.—The Columbian system of fireproof floors and roofs has met with a success unexampled, perhaps, in methods of fireproof construction. The brochure under notice is descriptive of the system, which consists in the use of heavy ribbed bars displacing the ordinary steel joists. The bars are surrounded and partly embedded in concrete, and by their peculiar shape form with it a monolithic roof or floor of great strength, and moreover fireproof. Many illustrations are given of the various forms adopted for different classes of buildings, with ample data of loads, tests, and spans.

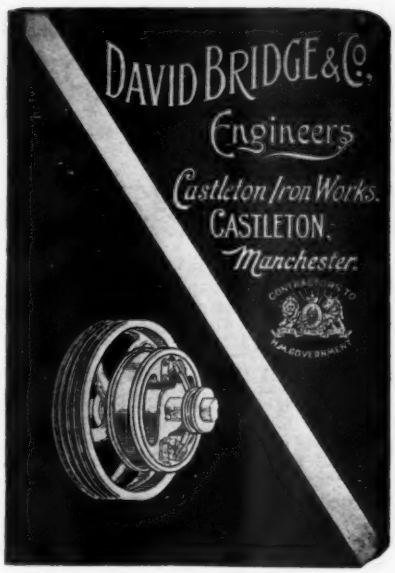
Mather & Platt, Ltd., Salford Iron Works, Manchester.—The second edition of a price list of "D"-type dynamos. These machines are of a neat, compact design, and are made in twelve sizes, with an output varying from 1 to 84 kilowatts.

A brochure descriptive of the Körting type of two-cycle gas engine, the manufacture of which Messrs. Mather & Platt have made arrangements to take up. It is gratifying to note that several leading firms have decided to devote serious attention to the manufacture of large gas engines, recognising the fact that this prime mover is rapidly gaining in favour amongst electric power and lighting station engineers. According to the brochure, a Körting engine has been built to develop 700 b.h.p. in one cylinder, and others are in course of construction developing up to 1,000 b.h.p., but it is not stated whether or not they are being made in this country. There are, however, several high-power internal-combustion engines working satisfactorily in Great Britain; but these were constructed at Middlesbrough. Messrs. Mather & Platt's brochure should be obtained and read by all interested in the matter.

Beyer, Peacock & Co., Ltd., Gorton Foundry, Manchester.—This catalogue gives in a convenient form particulars of characteristic types of locomotives constructed by this firm for the various railway gauges in use throughout the world.

Watson, Laidlaw & Co., Dundas Street, Glasgow.—The 1904 catalogue of this firm is one of the handiest, best printed, and well arranged publications of its class that we have met with. It is descriptive, of course, of the well-known patent water-driven Weston centrifugal machines and hydro-extractors, which appear to be, from a list accompanying the catalogue, in extensive use all over the world. The general description of the machines, which precedes the catalogue proper, is interesting, and deals with





those features which have contributed to make the "Weston" centrifugal so popular.

David Bridge & Co., Castleton, Manchester.—A well-arranged and attractive catalogue of the firm's improved patent friction clutches, which have the merit of being well-designed and particularly suited for difficult or very fast running drives. Messrs. Bridge & Co., being specialists in india-rubber and gutta-percha machinery, have also recently produced an advance catalogue descriptive of the machinery of this class, made by the late John Mills, of Oldham, and themselves.

A. Ransome & Co., Ltd., Newark-on-Trent.—General illustrated catalogue of Wood-Working Machinery, which is thoroughly representative of their general manufactures, and deals with portable forestry machinery, high-speed log-sawing machinery, sawing, planing and moulding machines, railway-carriage and wagon-building machinery, railway sleeper and key machinery, machinery for ship-building requirements, wheelwrights' machinery, pneumatic apparatus for the automatic collection of wood refuse, in addition to machines for ordinary every-day requirements. Copious notes accompany the numerous illustrations.

Ewart's Chain Manufacturing Co., Colombo Street, Derby.—Catalogue No. 24, dealing with Chain Belting, which this firm introduced some 25 years since for general power transmission purposes Its recognised advantages are:—A positive speed ratio; less wear on shaft journals and bearings; not affected by heat or damp; easily repaired. As it will not slip it breaks if strained beyond its specified working strain. The book is well got up with accurate illustrations and includes a description of the company's offices and works at Derby.

C. Redman & Sons, Pioneer Ironworks, Halifax.—On Yorkshire tools it has been customary to hear lately the highest encomiums passed, at least, that has been the experience of the editor of this publication. One firm of Yorkshire tool-makers, Messrs. Redman, have recently revised their patterns throughout, and introduced several new features, particularly in their planing machines. They are described, as are their up-to-date works, in a recent catalogue, which is very well printed and illustrated.

Gibbons Bros. Ltd., Dibdale Works, Dudley, Worcs.—A profusely illustrated catalogue of Elevating and Conveying Machinery of every description. Valuable Letters Patent are held by this firm for new and improved forms of chains-conveyors, elevators, etc., the illustrations of which are produced from photos of machinery in actual use. Special automatic machinery has recently been put down at the above works by means of which their chains and other specialities can be turned out at an exceptional rate of speed, and therefore at prices far below those possible when using older and slower plant.

Roberts Bros., Dukinfield, Manchester.—Grinding has, in modern workshop practice, become almost indispensable for economical and accurate production, and much of the high-class work that is being at present performed with shaping and milling machines could be more satisfactorily done by resorting to grinding. Messrs. Roberts Bros.' 1904 catalogue contains some very interesting details relating to disc surface grinding, as well as to the machine for this purpose.

John Lang & Sons, Johnstone, nr. Glasgow.—The all-absorbing topic of the moment in the machine-tool world is that of speeds, and with the idea of eliminating the drawbacks arising from the use of stepped cones, which involve work of diameters between those which are correct for each step being operated on at surface-speeds which are too slow, Messrs. Lang have introduced a Patent Variable Speed Drive, which appears to give very satisfactory results. In combination with a patent automatic speed-changing mechanism, the revolutions of the spindle are made to increase automatically as the diameter being turned becomes smaller, the tool cutting being thus kept at practically a constant surface speed. A well-illustrated booklet describes and illustrates the lathes fitted with these attachments.

Brunton, W. N. & Son, Musselburgh, Scotland. Price list of special galvanised arc-lamp rope, for which the makers claim that it is very flexible and many times more durable than manilla. Prices and particulars are also given of copper, iron, steel, tinned or galvanised sash cords.

WORKSHOP PRACTICE.

New Machine Tools.

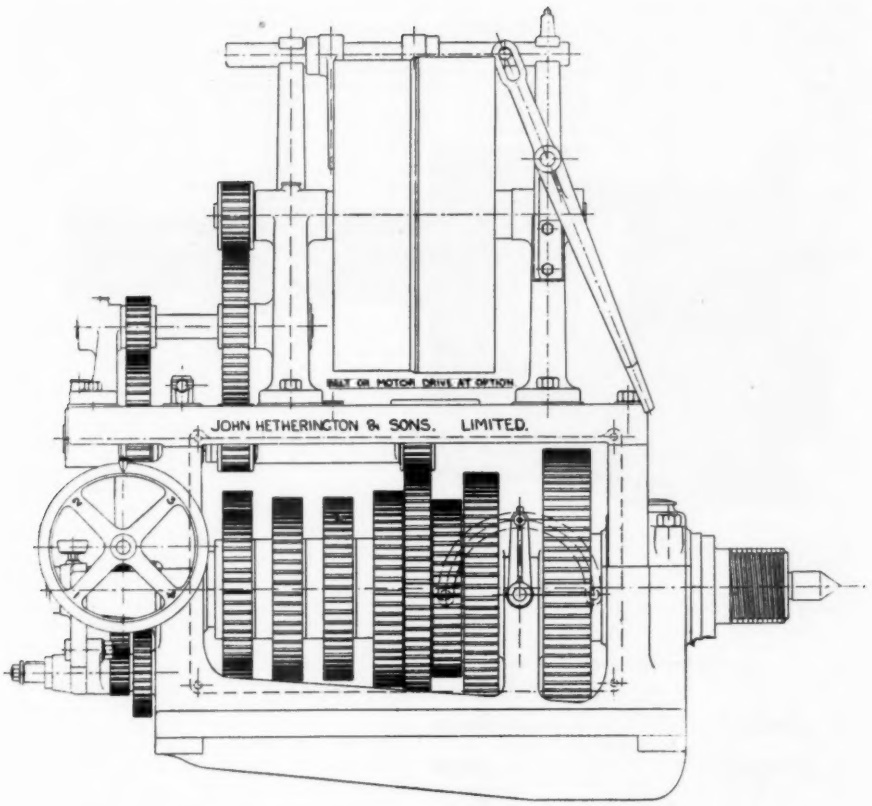
THE revolution now going on in machine tool building, consequent upon the demand for new types, to meet the requirements of the high-speed steels—now almost exclusively used in modern practice—has undoubtedly tested the ingenuity and brought out the latent energy of the designers. The recent exhaustive experiments with tool steel have provided an incentive, and fully demonstrated to machine-tool builders the necessity of providing better equipment. The purport of the present article is to enumerate the principal features of some new machines which are thoroughly representative of altered conditions. The innovations are striking—particularly in the gearing arrangements—as they mark a determination on the part of the builders to meet the exigencies thrust upon them by the advent of the new steels and the demand for machines which can utilise them to the utmost capacity. As evidence, Messrs. John Hetherington & Sons, of Manchester, have just issued a new type of high-speed heavy lathe in three sizes, one of which—14 ins.—we illustrate. It possesses all the essential features of a first-class double-geared lathe, mounted on a very rigid bed. The fast headstock, shown in side elevation, is driven by a constant-speed belt 7 ins. wide, running on pulleys 30 ins. diameter. The cutting speed is 100 ft. per minute, arranged through 12 changes of gears, from 2¼ ins. up to 14 ins. diameter, advancing in geometrical progression. The reduction gear may be similarly employed for changing down to a speed of 12½ ft. per minute when required for a finishing cut, or to operate upon harder material. A perusal of the tabulated speeds will be found most interesting. Between the driving-pulley brackets the space provides for electrical driving, if desired, by the substitution of a motor of about 30 h.p. The whole of the gears are machine-cut, and the front neck bearing 7 ins. diameter, both of which constitute particularly excellent features in a heavy lathe. The feed, ⅛-in. per revolution, makes the machine specially applicable for roughing-out purposes, whilst the reduction gear provides for accurate finishing.

Radial Wall Drill.

The new type of electrically driven radial wall drill, made by Mr. George Swift, of Halifax, Yorks, is somewhat different to the usual form of wall drill with which we are acquainted. It is self-contained and mounted on apparently a very strong frame, which is held in position by both floor and wall bolts. The frame carries a 3-h.p. motor, the power being transmitted to the first-motion shaft, upon which are mounted four spur-wheels, direct from the motor-shaft by a Renold silent chain, thus securing a positive drive. A second shaft carrying four loose gears, engages with other four gears on the second-motion shaft. On the latter, friction-clutches are keyed for throwing into gear any of the four changes provided by the combination of gearing. The machine shown in the illustration (p. 256) is suitable for the rate of speed and feed commensurate with high-speed steels, the amount of work being dependent upon the quality of the steel. The radial arm has a movement through 190 degs., the carriage thereon is moved by rack and pinion and controlled from the carriage. The spindle-feed is by the usual self-acting motion, through worm and worm-wheel, and may be automatic or hand. The length of arm varies from 3 ft. 6 ins. up to 6 ft., traverse of head 2 ft. 6 ins. up to 4 ft. 7 ins., range of spindle 12 ins. to 14 ins. The number of revolutions of the larger sizes are given as 250, and of the smaller up to 320 per minute.

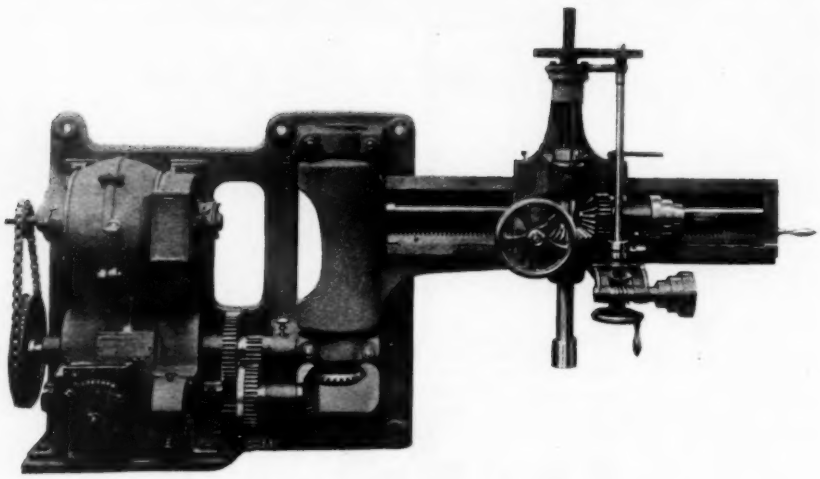
Thread Milling Machines.

The uses to which the milling machine may be put have apparently no limitation. One for milling threads in place of cutting them in the lathe has recently been issued from the works of the Pratt & Whitney Co., of Hartford, U.S.A. The machine, an in-

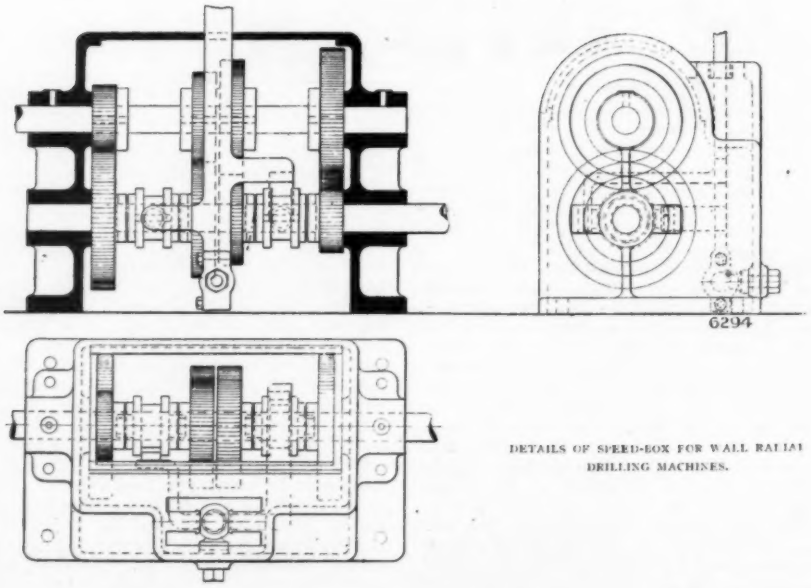


HIGH-SPEED LATHE BY MESSRS. HETHERINGTON AND SONS: DETAILS OF FAST HEAD STOCK.

teresting piece of mechanism, rests on a box-base having substantial and well-spread flanges, which give great steadiness throughout. The base contains recesses fitted up with cupboards for the accommodation of cutters, etc. A trough on the top forms part of the casting, and receives any oil which may be thrown off during the operations of the machine. The waste oil may then be drawn off at a convenient time and filtered for future use. The machine is built in two standard sizes—with a 3-ft. 6-ins. and a 9-ft. bed. The height of the machine centres will permit a spiral gear up to 6 ins. diameter being easily cut. A single V locates both head and tail-stock, whilst the saddle is traversed on flat slides, with large strips on the underside to prevent lifting. The head carrying the milling cutter is at the back of the saddle, the cutter spindle being driven by six round belts, each occupying a separate groove on the pulley. This unique driving arrangement is for the purpose of obviating the consequences attendant upon the breaking of a single belt, and the inevitable damage due to the stoppage of the cutter whilst the work was being fed forward. The necessary reduction of speed is effected by cut gearing, which is thoroughly lubricated by running in a bath of oil. The gears, which are fine pitch, are compensated for by extra width of face, but these with correct tooth form and perfect oiling are almost noiseless in action. Another distinctive feature is the mounting of the cutter carrier on horizontal trunnions, which allows



MOTOR-DRIVEN WALL RADIAL DRILLING MACHINE, BY MR. GEORGE SWIFT, HALIFAX.



DETAILS OF SPEED-BOX FOR WALL RADIAL DRILLING MACHINES.

the cutter to be tilted to any angle. This provision is most essential, as the cutters are made to the exact form of thread, and must be set to a relative angle to avoid the cutting of a groove of wrong form and width. The axes of rotation in the trunnion pass through the centre line of the cutter and through that of the screw to be cut. The special cutters which are used on the machine are set to depth by a micrometer adjustment, and in the cutting of multiple threads the work is moved into position for the next cut by a dividing arrangement. The ordinary type of pump keeps the cutter flooded with oil whilst at work. Other special features not enumerated considerably enhance the value of the machine, which seems capable of dealing with a great variety of pitches and forms of threads. The specimens of work range from a screw having an abnormal depth of thread, a helical gear with teeth at an acute angle, and a spiral spring produced by taking a deep cut in a tube. Some of the latter thus made are now being used on other machines built by the same makers.

Iron Castings.

When will our engineers begin to realise the necessity of giving some attention to one of the most important factors of the shop, viz. good and suitable castings? This is a subject which cannot be too forcibly impressed upon workshop managers, seeing that such detrimental results often attend the neglect of sound and suitable material. In too many cases the product of the foundry is treated as something of little moment, and very seldom do we find anything in the way of experiments or analyses to counteract repetitions of bad castings. A paper recently given by Mr. Morehead, before the Rugby Engineering Society, proves conclusively that the subject is of vital interest to those who are desirous of getting the best and most perfect castings from the foundry. The experiments detailed by the author of the paper are innovations seldom met with in British engineering firms or large foundries, though by no means rare in American and Continental ones. Some few years ago a pamphlet was issued by a notable firm of Continental tool builders which embodied many of the remarks contained in Mr. Morehead's paper. These, however — though widely circulated—did little to encourage inquiry into the work of the foundry. The gist of Mr. Morehead's remarks is that a great deal of the faulty casting is ascribable to impure coke and iron and the incompetent manipulation of the furnace. He says that, of late years, the efficient working of cupolas has received considerable attention. From a personal experience extending over thirty years, we are sorry to say from this statement we must dissent. Very little indeed has been done in the shops, certainly nothing commensurate with the improvements in the other departments, and the foundry to-day appears pretty much the same as it did a quarter of a century ago. The vocation of the moulder is an arduous one, and does not tend to encourage studious men; but it is a pity that so few foundry foremen take so little interest in the metallurgy and the properties of the materials which are, or should be, under their control. It is not the coke, iron, or improper melting that is mainly responsible for bad castings, but very often the carelessly prepared moulds; and no matter what amount of care is bestowed on the selection of material, it all goes for nothing if proper moulding is neglected. This includes imperfect venting of both moulds and cores, unsuitable runners, and the absence of "risers"; the latter being an omission that is responsible for the majority of shrunken castings. The "riser" is a far more important adjunct than most moulders are aware of, as it provides a means whereby the castings can be made more homogeneous and porosity prevented to a very great extent. Through the "riser" the casting can be "fed," and by this operation the confined gases are expelled and the solidity of the casting ensured. As an alternative to a riser —in the case of castings run vertically—an excess beyond the actual length should be left on the casting. This portion receives most, if not all, of the dirt, and also encloses the cavities formed by the insoluble gases which otherwise would form beneath the surface of the castings. Large moulds should at all times be well vented, preferably by cinder beds, freshly laid down and prepared with good material. Every facility for transporting the free gases should be made, in the way of tubes having direct communication with the cinder bed. Another source of danger is the insertion of cores just out of the stove. These cause the moulds to "sweat," generating vapour, making the surface friable and liable to crumble, and producing in many instances "scabbed" castings. With these few but important facts before us, it is imperative on the part of those having the supervision of a foundry to make sure that the moulding operations have been properly conducted, then, with systematic methods in regard to the cupola and some attention to the mixing of the iron —pig and scrap—we shall have obtained the solution of how to make a sound casting.

Boiler Tubes.

The much-debated question of the superiority of the water-tube boiler over that of the cylindrical type, may be a little further elucidated by perusing the following remarks in reference to the materials used in construction :—

It has been generally admitted that the success or failure of a tubulous boiler is largely due to the strength of the tubes, and the writer is therefore desirous of pointing out seriatim the causes by which they are affected.

Let it first be remembered that the effect of the material on evaporation is *nil*. Take two similar tubes, one of copper and the other of iron, and it will be found that the heat transmitted is practically the same in both cases, though the heat conductivity of the former is seven times that of the latter. Blechynden's * and other experiments have also shown us that the thickness of the metal is of little consequence as regards transmission of heat, and in face of this it is surprising to find engineers advocating an increase of evaporation by making heating surfaces of thin material and of good conductivity.

The failure of boiler tubes is probably owing to one or more of the following causes: (1) Corrosion on the water side; (2) Corrosion on the fire side; (3) Overheating and oxidation; (4) Deposition of mineral salts and grease; (5) The action of the steam; (6) Diminished tensile and compressive strength, and defective material; (7) Insufficient elasticity; (8) Erosion.

Corrosion on the "water side" is due to —(1) The presence of acids in the feed-water; (2) The lubricant; (3) Galvanic action. Corrosion on the "fire side" is due to—(1) Leakage; (2) The action of the gases formed during combustion. Overheating and oxidation is due to—(1) The hot gases; (2) Shortness of water; (3) The collection of deposits—mineral salts and grease.† Steam, if superheated, is liable to be decomposed, and this greatly accelerates corrosion, thus producing diminished tensile and compressive strength owing to the high temperature. Insufficient elasticity aggravates undue strains in the material, and ample room for expansion should be provided; if not, collapse must result. Erosion is due to solid particles colliding with the surface—an action which creates a sort of sand blast; erosion of the tubes due to this cause is very noticeable in locomotive boilers.

All the better-known metals used by the engineer have been adopted for the manufacture of boiler tubes, and each has been abandoned by one boiler-maker or another, only to be re-adopted years afterwards, because a man finds that his keenest competitor is using it successfully. We find that Yarrow and Thornycroft abandoned steel for brass, and returned later to steel. Brass has the peculiar property of developing minute cracks on being drawn into tubes; but Yarrow abandoned galvanised steel tubes about 1884 in favour of "crack-free" brass tubes, which he claimed to have produced; latterly, however, he has returned to galvanised steel. Thornycroft at first used brass, then steel (at the suggestion of Mr. Yarrow). Perhaps the unsatisfactory elastic qualities, or perhaps the cost, had something to do with the final abandonment of copper alloys in the manufacture of tubulous boilers. Normand at present uses mild steel, and says that it is the only reliable material; he expresses his entire satisfaction at its behaviour under the most severe tests. Copper would undoubtedly last much longer, but in the case of bursting, the tube opens out fully, allowing the steam and water to escape through double the section.

In locomotive boilers it is remarkable to find that copper, brass, steel, and iron tubes are used successfully—the two former by English engineers, and the two latter by American engineers, who abandoned copper and copper alloys. Webb was the first to allow for the free expansion of boiler tubes, by giving them a camber of about an inch at the centre. The life of locomotive boiler tubes is, on an average, about three years, the rapid deterioration being principally due to erosion, as already stated.

Copper and brass tubes are invariably made seamless, either by drawing from a rod, or by electric deposition, and an excellent plant has recently been installed for the manufacture of tubes by the latter process at the works of The English Electro-Metallurgical Co., Ltd., situated at Leeds.* The copper is electrically deposited upon rotating brass or iron mandrels, upon which a rotating agate burnisher traverses. When sufficient copper has been deposited, the mandrels are removed from the bath and passed over by friction rollers; the mandrels are removed by suitable appliances, and, if required, the tubes can finally be expanded in the usual manner, and annealed in a closed retort heated to dull redness. The "extrusion process" does not as yet appear to have been applied to the manufacture of copper and brass boiler tubes.

* See Proc. Inst. N. A.
† Proc. Inst. N. A.

* *Engineering*, May 17, 1902.

The bursting of lap-welded iron and steel tubes led to a fruitful discussion, in which many of the leading boiler-makers took part; but opinions are still divided as to which are the best. Experience leads one to believe that tubes of the former kind are liable to a slow opening of the weld, and there is always the possibility of a defective weld—two drawbacks totally absent in seamless tubes. On the other hand, in drawing a tube, molecular change of the material may occur; but this is perhaps the lesser of the two evils.

Two other materials only claim attention, and they have had but a limited application up to the present, but their properties come very near to the ideal material from which to manufacture tubes. They are nickel steel and aluminium bronze. The former was introduced and experimented upon by Mr. Yarrow,* on the recommendation of the Dutch Government. In a corrosion test, using dilute hydrochloric acid (an acid often met with in feed-water, especially in marine boilers), it was found that the corrosion of a mild steel tube was 16·5 times as great as that of a nickel steel tube. In another experiment, the fire test, the loss of weight of the mild steel tube was 2·9 times that of the nickel steel tube; and from the superheated steam test Yarrow concluded that deterioration of a boiler from this cause would require mild steel tubes to be replaced 2·3 times as often as nickel steel tubes. The suitability of nickel steel, from a mechanical point of view, was admirably illustrated by the specimens exhibited by Mr. Yarrow.

Dr. Waldo† claims to have produced an aluminium bronze—a compound, not an alloy—of great strength, even at high temperatures, and of excellent ductility, and he prophesies its general adoption in the near future for the manufacture of boiler tubes.

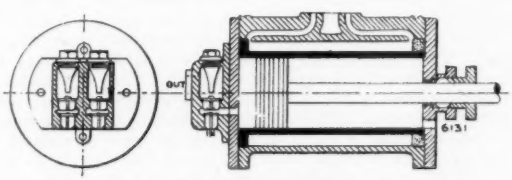
In the two latter cases, great difficulty was at first experienced in drawing the tubes, but the Mannesmaun process, modified, has rendered the work comparatively easy. Nickel steel is certainly a costly material to produce, but the increased life of a tube of this material over a tube of mild steel compensates this extra initial cost. As regards aluminium bronze, the days are now over when aluminium cost £300 per ton. It can be bought to-day for the price of copper, so the question of cost will sink into insignificance if an aluminium bronze can be found suitable for the purpose.

H. H. B.

* Proc. Inst. N. A.
† Proc. Am. Soc. M. E.

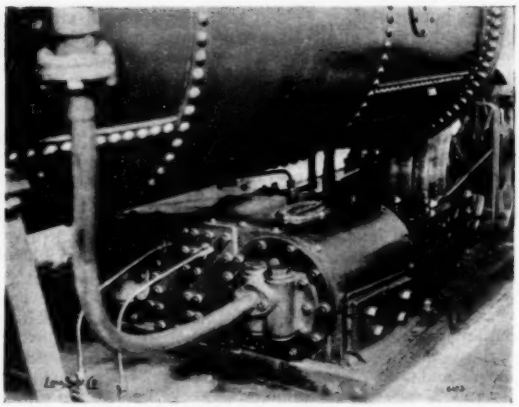
Making an Air Compressor.

The advantage of the use of compressed air, its adaptability, cleanliness, safety, and the ease with which it can be manipulated, are so well known that those who are the fortunate possessors of an installation are surprised that they managed for so many years without it; and those who are debarred from its adoption, either by the initial expenditure or kindred objections, look forward to the time when they will be enjoying the same advantages as their more opulent or fortunate contemporaries. The time has gone by for considering the *advisability* of adopting this form of energy. Having passed the experimental stage, the question is now, not "*shall* we have it?" but "*how* shall we obtain it?" also "which is the best form of plant and tools?" Of the latter little need be said; tools are being supplied in this country that are beyond praise, and, from the commencement of this industry greater success appears to have attended the manufacture of tools than of compressors, particularly in the case of those driven by belts. My experience of the earlier forms of compressors has not been encouraging. History appears to have repeated itself in perpetuating the same errors—now remedied—that dogged the steps of the earlier machine makers, in listing the compressors beyond their average capacity of delivery, combined with insufficient driving power and unreliability of the working parts, notably the valve gear. Experience has now evolved compressors that will run continuously for any length of time without attention, and can be depended upon to keep up the finger of the pressure gauge. This result has not been achieved without cost, which has no doubt influenced the price-list; and small or struggling works, whose finances are not in a robust condition, but who find the

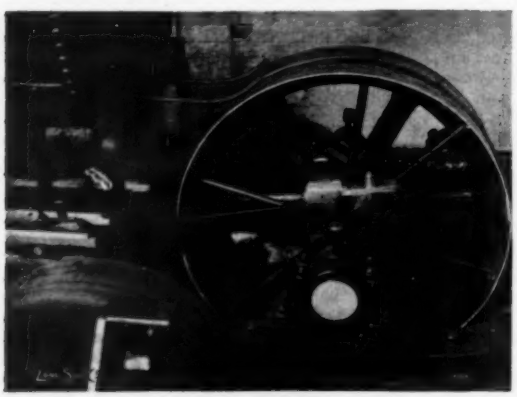


MAKING AN AIR COMPRESSOR: DETAILS OF VALVE-BOX, CYLINDER, ETC.

comparatively cheap drills, hammers, etc., within their reach, are sometimes compelled to forego the advantages of the system on account of the initial cost of a good compressor plant. Such has been the writer's experience, and possibly that of many others, the difficulty in the present case being surmounted by constructing a compressor out of such odds and ends and spare engine parts as are usually to be found in a general shop; and as it proved satisfactory, I venture to give it for what it is worth. We had originally a small compressor that was quite inadequate, and the ratchet-brace was often brought into action because the compressor would not supply sufficient air to keep the tools working continuously. A constant supply of air at full pressure was necessary to make its use popular. We had, fortunately, the working parts of a broken-up locomotive—the slide-bars, crossheads, connecting-rods and crank, and inside cylinders 12 ins. diameter by 18 ins. stroke. The cylinders were larger than required, and were therefore bushed to 8 ins. diameter, as shown in the diagram, a flange being cast on one end of the bush and a loose ring-flange fitted to the other end; both flanges a driving fit in the bell-mouth of the cylinders, the covers making the joint both for air-pressure and water-jacket. This bush also gave an ample water-jacket around the cylinder walls, the water flowing through the ports and out at the top of the steam chest. The same result might be obtained from a pair of ordinary flanged pipes. Pedestals were made to carry the crank, and the rods and slide-bars were coupled in the usual manner and fixed on a cast-iron inverted trough section-bed. From the fly-wheel of a shearing machine a wheel was cast which also acted as a fast-driving pulley; a loose pulley of light construction was also made $\frac{1}{4}$ in. less in diameter. The jacket water was taken from the works main by two $\frac{3}{8}$-in. diameter pipes, and entered the cylinder jackets at the bottom at a temperature of 48 degs., leaving at the top of the steam chest at a temperature of 80 degs. The receiver—an old boiler barrel—was placed horizontally above (for want of space) on two wrought-iron legs, and was fitted with a lever safety valve. The cylinders were made single-acting by leaving the back cylinder cover open to the atmosphere, and fixing inlet and outlet valves on each of the front covers, provision being made to fix a valve-box on to the back cover, should it be found necessary to provide a greater volume of air than could be obtained from the single action. It was also arranged that one cylinder could be thrown out of operation, should the supply



MAKING AN AIR COMPRESSOR: VIEW OF CYLINDER ARRANGEMENT, BED, ETC.



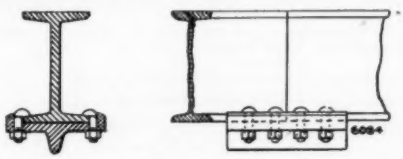
MAKING AN AIR COMPRESSOR: VIEW SHOWING STRIKING GEAR, PULLEY, FLY-WHEEL, ETC.

be beyond the requirements, by introducing a two-way cock in the delivery pipe of one of the cylinders, by means of which air could either be passed into the receiver or allowed to escape into the atmosphere. The piston was simply a solid block fitted with three bronze rings $\frac{3}{8}$ in. wide and $\frac{1}{4}$ in. thick; the piston was lengthened to fill up the clearance spaces at the ends of the cylinder, only $\frac{1}{32}$ in. being allowed between the piston and cylinder cover at the end of the stroke. The inlet and outlet valves were of the simplest kind—ordinary poppet valves with gun-metal seats. It is possible that more efficient valves might be constructed, but none that would give less trouble. The air is drawn into the cylinder through the lower valve, whose lift is regulated by the lower end of the upper valve, through which the air is delivered into the pipe leading to the receiver. The fast pulley, or fly-wheel, is driven by a 7-in. belt, and revolves at a speed of 64 revolutions per minute, the belt being moved on the pulleys by means of an ordinary striking-gear. The photograph of the cylinder ends shows the arrangement of the valve-boxes, pipes, fixing of cylinders, and bed, with the receiver above; the other photograph illustrates the arrangement of striking gear, fly-wheel, loose pulley, pedestal, and crank, the slide-bars and beds being covered partially by the pulleys of an adjoining machine. The scale drawing will give an idea of the valve-box, piston, cylinder, and bush, a vertical section through the valve-box and a horizontal section through the cylinder being combined. This compressor has been working for 20 months without requiring one hour's repair; occasional lubrication is all that has been necessary. The starting-gear is under the control of an adjacent machinist, who regulates the running of the compressor in accordance with the pressure-gauge reading. The leading dimensions are as follows: Length of receiver, 10 ft. 4 ins.; diameter, 3 ft. 10 ins.; diameter of cylinder, 8 ins.; stroke, 18 ins.; diameter of fly-wheel, 4 ft. 3 ins.; diameter of inlet valves, $1\frac{3}{4}$ ins.; diameter of delivery, 2 ins.; width of belt, 7 ins.; temperature of jacket-water; inlet, 48 degs.; outlet, 80 degs.; capacity, 80 cub. ft. of free air per min. compressed to a pressure of 80 lbs. per sq. in.

WORKS MANAGER.

Joint for Small Girder Work.

The above is a handy form of joint for small girder work, such as used for engine-room floor-plates, semi-portable erections, etc., where it is not desirable or convenient to drill holes in the girders. This joint-bracket is simply a casting, no machining



JOINT FOR SMALL GIRDER WORK.

whatever, and only requires sliding into place and clamping by the hook-bolts. By reference to the illustration it will be seen that the backs of the hook-bolts are supported by the metal being carried up behind each one, thus preventing the weight from opening the bolt and releasing the fixing. H. L.

QUERIES.

Dynamometer for Propeller Thrust.

Will some reader let me know the best and most easily attached dynamometer for above use? The i.h.p. is about 225, and runs at about 350 revolutions per minute. Will it necessitate a special thrust block?—EXMOUTH.

Skin Friction.

In passing from the model of a ship to the ship itself, what correction must be made for skin-friction?—EXMOUTH.

ENGINEERING ABSTRACTS

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MATERIALS AND MEASUREMENTS.

Cement Mills.

In some mills centrifugal force is utilised, and the cement is pulverised between a fixed crown and heavy balls working in guides, and actuated by the rapid rotation of th centre shaft. In other types, the cement is crushed by a succession of blows produced by th fall of heavy balls of steel moving freely in rotating cylinders. Among mills with balls working in guides and at high speed, may be mentioned the Griffin, the Morel, and the Phœnix mills. In the Griffin mill the material has to be reduced to grains of a few millimetres before introduction. This mill turns out 1,500 kg. per hour, with a fineness of 25 per cent. on a 4,900-mesh sieve—the force absorbed being about 25 h.p. In the Morel and Phœnix mills the hourly output is 1,000–1,200 kg. —the power required being 15–20 h.p. In the Clero high-speed mill, there are two discs fixed on a spindle, and to which beaters are attached—being pivoted so as to swing freely. The mill is actuated by pulleys at the ends of the spindle, and is enclosed in a case with a hopper for the admission of material. Baffle plates are fitted to check the upward flying fragments, and in the bottom of the casing two curved and perforated plates are provided, through which pulverised cement falls into the buckets of a conveyer. Ball mills are made upon different models—the principle being usually the same—but they do not in themselves reduce the clinker sufficiently fine, and the auxiliary use of the tube-mill becomes necessary. This apparatus consists of a horizontal cylinder containing a number of flint pebbles. As it slowly rotates, the pebbles pound against the material and gradually reduce it to fine powder. In the Davidsen tube-mill the material is introduced through a hollow shaft at one end, by means of a worm. As the cylinder rotates, the material is pulverised, and moves along towards the other end, where it finally emerges in a finely divided condition.—**A. Morel,** *Gén. Civil, Vol. XLIV, No. 6,* pp. 88, 89.

Wrought Pipe.

The author commences his paper with a description of the origin and development of the wrought-pipe industry. Having set forth the respective advantages of the butt-welding and lap-welding processes, he decides upon the superiority of the lap-weld process for actual use. The varieties of screw-joint pipes are then discussed and classified, the holding power or shearing strength of a screw joint being proved to be much greater than is generally supposed. In the rest of the paper the author deals with the wrought-steel pipe, and shows in three tables, relating to tests by hydrostatic pressure, and also tensile and corrosive tests, that it can more than hold its own against wrought-iron pipe. In connection with the last-named test he says: "No matter whether we use wrought-iron or steel pipe, corrosion is a factor that cannot be ignored"; next describing how pipes can best be protected against this danger. The paper concludes with specifications for merchant pipe and line pipe.—**F. Riffle,** *Machy., Vol. X, No.* 4, pp. 191–193.

Effect of Clay and Loam on Cement Mortar.

The investigation here described was for the purpose of determining whether or not a moderate proportion of clay or loam is injurious to cement mortar. The materials used were Dyckerhoff and Lehigh cements, lake, bank, and crushed quartz sand, finely pulverised clay, and finely ground loam. In mixing the mortar the proportion of 1 part of cement to 3 parts of sand was used. Where clay was used it was taken as a percentage of the sand, so that the proportion of 1 to 3 was maintained. The results were plotted in curves for age in months, to make them comparable with other long tests, which are usually given in months. In 72 curves, representing the strength of mortar containing different proportions of clay or loam, only five fell below the zero per cent.; and the 15-per-cent. mixture of clay and loam proved to be the stronger at the end of one year in eight cases out of twelve. We may conclude, therefore, that clay or loam up to 15 per cent. is beneficial to cement mortar. If, however, the mortar is to be placed immediately under water, more than 8 per cent. would cause some trouble, as it takes longer to reach its final set. It would appear from the diagrams that the longer time tests give the most uniform results. As to whether the strengths of the mortars tested is permanent or not, we think it safe to say that it is permanent. The writer is satisfied that time and money spent in washing sand for Portland cement concrete is wasted; and that the importing of lake sand, frequently specified at many places, is often unnecessary. The insurance of a clean aggregate is of much more importance, especially if the concrete may be subjected to a tensile stress.—**C. E. Sherman,** *Eng. News, Vol. L, No. 21,* pp. 443, 444.

A Steam- and Electrically-Driven Cement Plant.

This article contains a description of a new and unusual kind of cement-making apparatus, situated near Stewartsville, N.J., and designed under the direction of Mr. Thomas A. Edison.—**Anon.,** *Eng. Rec., Vol. XLVIII, No. 26,* pp. 796–802.

ENGINEERING PHYSICS.

Experiments in Radio-activity.

The first part of this paper gives a summary of our present knowledge of the nature and properties of radium; in Part II. the author describes some experiments on radio-activity carried out by Lord Blythswood and himself at the Blythswood laboratory. The increase of conductivity of the air when radium radiation is present is shown by arranging two spark-gaps in parallel, one being exposed to the action of radium while the other is screened. If the length of the gaps is adjusted so that sparking takes place at both simultaneously, it is found that the gap influenced by the radium is the longer of the two. On experimenting with

various lengths of gaps it was found that as the gap increased so did the difference between the two gaps, until for a gap of 3mm. the difference amounted to 15 per cent. when spherical terminals were used, and after this the difference again diminished. With point terminals the difference was again most marked for a gap of 3 mm. or 4 mm., but in this case the spark-gap exposed to radium radiation was three or four times as long as the other. Following up J. J. Thomson's discovery of radio-activity in Cambridge tap-water, the present experimenters made an examination of water from the hot mineral springs of Bath, and found that it also gave off a gas which behaves in a manner similar to the emanation from radium. It is at present uncertain whether this gas is identical with the radium emanation or whether it corresponds to some other known or unknown radio-active element. Water from the Harrogate sulphur springs, which are not deep-level waters, showed no radio-activity, but Buxton water gave results like those for the Bath waters. The author throws out the suggestion that the therapeutic action of the Bath waters may be due in some degree to the radio-activity of the gases contained in them; and if this be so, the fact that the activity of the gas begins to decrease very soon after the gas is liberated may possibly afford an explanation of the belief that the waters of certain spas possess greater efficiency when used on the spot than when removed to be consumed elsewhere.—**H. S. Allen,** *Engineering, Vol. LXXVI, Dec. 4, 1903,* pp. 781–783. (Paper read before the Royal Philosophical Soc. of Glasgow, Nov. 18, 1903.)—*W. C. H.*

CONSTRUCTION.

The Effect of Stresses on Cantilevers and Beams.

THE author considers a simple approximate method of determining the deflection (S) of levers under various conditions of load, etc. The following are the formulæ derived: — (*a*) For an ordinary cantilever of uniform section (with the weight at the free end)— $S = \frac{Wl^3}{3EI}$. (*b*) Suppose the lever to be of equal strength throughout, and let the depth be constant and the breadth vary, then $S = \frac{Wl^3}{2EI}$. (*c*) If the lever be of uniform strength with constant width, we have $S = \frac{2Wl^3}{3EI}$. (*d*) Now let the weight be placed at any point distant x from the free end, and let the section be uniform, then $S = \frac{Wl(l-x)^2}{3EI}$. (*e*) If depth and unit stress are constant, then $S = \frac{Wl(l-x)^2}{3EI}$. (*f*) If breadth and unit stress are constant, then $S = \frac{2Wl(l-x^2}{3EI}$. (*g*) If a beam be taken and supported at both ends, and a weight placed at its centre, then, if the section be uniform, we have $S = \frac{Wl^3}{48EI}$. (*h*) If the beam be of uniform strength, with breadth varying, we get $S = \frac{Wl^3}{32EI}$. (*i*) If the strength be uniform, with depth varying, we have $S = \frac{Wl^3}{24EI}$. (*k*) Now consider a beam of length l, supported at both ends, and a weight placed at any point distant x from the nearest support, and suppose the lever of uniform section, then, if R^1 = reaction of farthest support, $S = \frac{R^1 l^3}{24EI}$. (*l*) If unit stress and depth are constant, then $S = \frac{R^1 l^3}{16EI}$. (*m*) If unit stress and breadth are constant, then $S = \frac{R^1 l^3}{12EI}$. (*n*) For a cantilever of uniform section with the weight uniformly distributed along the length, $S = \frac{Wl^3}{8EI}$. (*o*) If the lever be of uniform strength, with unit stress and depth constant, then $S = \frac{Wl^3}{4EI}$. (*p*) If the strength be uniform with a constant breadth, then $S = \frac{Wl^3}{2EI}$. (*q*) Beam supported at both ends, and weight uniformly distributed, and suppose the section to be uniform, then $S = \frac{5Wl^3}{384EI}$. (*r*) If the beam be of uniform strength, with breadth varying, then $S = \frac{Wl^3}{64EI}$. (*s*) If the strength be uniform with constant breadth, then $S = \frac{Wl^3}{96EI}$. (*t*) If a beam be fixed at both ends, and a weight be placed at the centre, then before the deflection can be calculated it is necessary to ascertain the point at which the bending moment vanishes between the support and the centre. The total deflection is equal to the sum of the deflections of the two parts, into which the half length is divided by the vanishing point. $S = \frac{Wl^3}{192EI}$. (*u*) If the load be uniformly distributed along the length, $S = \frac{Wl^3}{384EI}$. The derivation of the foregoing formulæ is demonstrated in detail, and illustrated by seven diagrams.—**T. Mackenzie,** *Builder, Vol. LXXXV, No. 3173,* pp. 538–540.

The Latest Progress in Shaft Sinking.

As shaft sinking has greatly increased of recent years, many endeavours have been made to improve and accelerate shaft sinking methods. In this paper the author first considers the usual method of shaft sinking in hard ground, involving actual labour in the bottom of the shaft, accompanied by pumping of all water which may be encountered. In ground which carries water, there are still only three accepted methods of sinking—the old system of drop shafts, shaft boring on the lines of the Kind-Chaudron method, and the freezing method. The author then goes on to describe two or three drop shafts that have been sunk, one of which was damaged

in its lower portion by longitudinal fractures, and by buckling. The causes and remedies for such damage are given in great detail. Eight important works carried out by means of drop shafts with hydraulic jacks are described. Shaft sinking by boring is then discussed, also the details of a few characteristic enterprises. The author concludes with some general remarks upon shaft drilling and tubbing at great depths, and gives a table containing a list of shafts sunk to date by means of the Kind-Chaudron system. This paper is accompanied by several drawings and photographs, illustrating the different processes in shaft sinking.—**Chief Engineer Riemer**, *School of Mines Qtrly., Vol. XXIV, No. 3*, pp. 361–400.

Preventing the Moisture of Walls.

AFTER demonstrating by laboratory experiments the validity of the hypothesis that to bricks—impregnated with vegetable oils—are imparted the property of being water-proof, the author suggests utilising this fact for treating bricks of such walls as are in immediate contact with the moist ground.—**F. Walter,** *Zeitsch. des Oesterreich. Ing. u. Architek. Vol. XL, No. 50*, pp. 666–671—*A. G.*

The Sanding-up of Tidal Harbours.

THE author first deals with the effect of the disturbance of the balance of the littoral forces on a tidal foreshore by solid works, and of the principles which regulate the construction of groynes. The object of the Paper is to indicate the effects of sanding-up in harbours situated (1) where no river debouches, and (2) at the mouths of rivers or estuaries. The author refers to the historical side of the question, as detailed in Minard's "Ports de Mer," to show the futility of merely prolonging entrance piers into deeper water. He points out that the entrance of the harbour of Sta. Ana, Curaçao, although an ideal natural harbour, was permanently narrowed by a hurricane in 1877. Reference is next made to the expedient of sluicing-basins, as to which particulars are given of that under construction at Ostend, and an opinion expressed generally adverse to the adoption of the system. The author then describes the measures taken to dredge and maintain the channels to the Port of Ostend. Of three channels, one is now abandoned and the other two are kept clear by the annual dredging of 950,000 cub. m. Similarly the Port of Boulogne requires the annual dredging of 535,000 cub. m. He considers that dredging is the only satisfactory expedient for conserving working depths at the mouths of sand-threatened harbours. He quotes Littlehampton as an instance of a permanent harbour at a river-mouth, but points out that the entrance is almost dry at low-water. Stress is laid on the character and coarseness of sand as an important factor in its travel, and the method of travel along a sea-bottom is described. By means of diagrams the action of the flood and ebb travel on coast lines having standard contours, and various arrangements of breakwaters and piers, is demonstrated, showing in each case the position of the shoaling which results. By a further series of diagrams the author demonstrates the contingent effect of a prevailing wind. Viaduct piers cause no disturbance of the coastal *régime*. As an actual instance of the extinction of a harbour by sand, the author gives particulars of the obliteration of Ceará Harbour, Brazil, a work which occupied ten years and cost over £400,000. He then gives the various stages of the harbour of Madras, details the original studies of the late Mr. W. Parkes, and the changes in the contour of the coast which resulted from the first two years' working. Attention is called to the fact that a progressive shoaling of the entire area of the harbour up to the original 7½-fathom line has resulted, and the substance of the opinion of the late Sir Andrew Clarke, in his Report to the Indian Government as to the position of affairs in 1879, and his recommendations at that date, is given. The Commission of 1882 and their recommendations, and those of the mixed Commission appointed by the Indian Government in 1883, are referred to. The author quotes their opinion that unless the opening of the harbour as designed were closed, and a new opening to the north-east substituted, the harbour would prove valueless as a shelter for shipping. Reference is made incidentally to the sanding-up of the harbour of St. Catherine's, Jersey, a work on which £200,000 had been expended; and some details are given of the early history of the Royal Harbour of Ramsgate, with the opinions of Smeaton and Rennie. The Paper then deals with the question of harbour construction on the west coast of Denmark. The problem on the east coast has been the impediment due to ice, but this is now disposed of by the use of ice-breakers. On the west coast the only harbour is that of Esbjerg, and, with this exception, fishing-boats have no shelter except the mouth of the Limfjord. At Hirtshals a large Government harbour was projected at a cost of £550,000, and the works were started in 1879. The work is now sanded-up and abandoned, except that the pier has since been prolonged. The author subsequently advocated the utilisation of the Ringkjöbingfjord, and submitted plans of an isolated harbour connected by viaducts with the shore at Sandnæshage, a favourable spot owing to the depth of water there and the protection of an outlying reef. A Fishery Association has been actively at work, and the Government has recently published the Report of the Royal Commission on the subject of harbour accommodation. The Government has now determined on the construction of a small harbour at Skagen and of two isolated moles, respectively, at Hanstholm and Vorupör. The author concludes that in view of the precarious nature of tidal harbour work, and the instances in which success has been only partial, a departure from established practice is called for. Harbours of refuge have a limited range of utility, unless in land-locked positions. The opinion is expressed that in a number of instances it would be practicable, by means of piled structures, to create shipping facilities which would meet reasonable requirements, and come within the resources of municipalities or local authorities, also avoiding the permanent expense of dredging. Such structures would, however, have to be most carefully designed, more especially

in relation to their height, cranage, and the moorings for vessels frequenting them.—**A. E. Carey, M.Inst.C.E.,** *Proc. Inst. Civil Engrs., Jan. 1904.—C. E. A.*

Proposed Thames Barrage.

It is proposed to construct across the river at Gravesend a barrage, similar to those across the Nile, with sluices and a series of very large locks, the dam to hold up the river to about Trinity high-water level. The position of the barrage is shown in Fig. 1, and the author thus describes its effect upon the business and usage of the river, assuming the work to have been carried out:—(1) Ships drawing 30 ft. can then proceed to London Bridge without waiting for tides; (2) ships of all tonnages and draughts can anchor anywhere, lay alongside any quay, always remain at one level for loading or unloading, and need not lie out in the river or obstruct the free navigation; (3) dock entrances can be left open, thus saving the cost and time lost in working them; (4) there will be no mud entering the docks and backwaters; (5) exceptional tides will not overflow the river banks; (6) reduced cost of towage, repairing river banks and control of the river; (7) greatly increased safety of navigation, the tides being responsible for most of the accidents and for many lives lost. Perhaps the most important advantage created by the barrage will be the permanent supply of water for the increasing demands of the London area. It is proposed that the Thames "lake" should be regarded as a storage reservoir, so far as water supply is concerned. It will contain sufficient for 320 days' supply. There also remains to be mentioned the opening of a railway communication across the river by a tunnel under the barrage, and of road communication by a roadway over it, as shown by the section in Fig. 2. To carry out the proposals of this article it is intended, in the ensuing Session of Parliament, to promote a Bill to create a Board of Harbour Commissioners, somewhat on the lines of the Port of London Bill of last Session.—**T. W. Barber, M.Inst. C.E.,** *Pub. Wks., Vol. II, No. 1,* pp. 17–33.

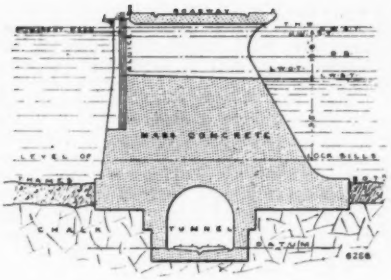


FIG. 2.—PROPOSED THAMES BARRAGE.

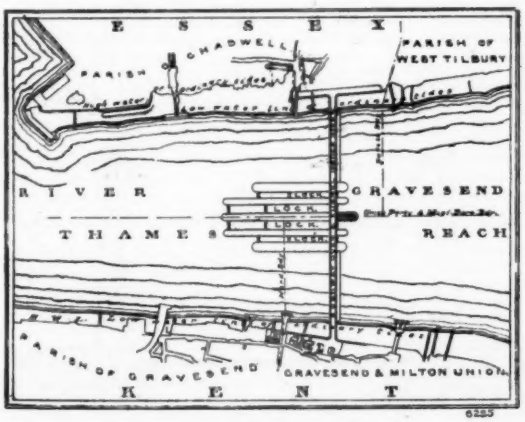


FIG. 1.—PROPOSED THAMES BARRAGE.

Bridges for Electric Railroads.

In view of the heavy cars now in common use on urban and interurban lines, it is necessary to examine into the city bridges, as well as the county bridges, which are used by the railroad companies. When railroads left the highways it became necessary for the companies to erect bridges of their own. Many of them have built bridges for present needs only, and designed for passenger and express traffic only, when in the near future it may be desired to haul heavy freight loads over the lines. The writer has given considerable attention to the probable maximum loading required to be carried by a given bridge, and recommends the adoption of load tables based on the specifications of the Osborne Engineering Company for electric railroad bridges. These loads range from a train of 40-ton passenger cars to one of 50-ton coal cars. In the majority of cases bridges are strong enough to carry the loads, or it is possible to make them so with slight changes and repairs, but there are many cases where they are seriously overloaded. The most common point of weakness in a bridge designed for highway traffic, and later used for electric railroad traffic, is in the floor system. In the practice of the Osborne Engineering Company impact is taken care of by adding to the live-load stress a percentage determined by the formula $I = \frac{L(L)}{L+D}$, in which I = the impact to be added to the live-load stress; L = the live-load stress; D = the dead-load stress. The term "factor of safety" of a bridge is misleading, as, when ordinarily used, it means the ratio of the ultimate strength of the material to the actual stresses caused by the dead and live loads, not considering impact. In the first place, the factor of safety should be based

upon the elastic limit, and not upon the ultimate strength of the material. In the second place, it is necessary to take the effect of impact into full consideration, in order to determine the actual stress in each member of the bridge. Complying with these two conditions, the bridges designed under the specifications which are given by the author at the conclusion of his paper have a factor of safety of two. The writer believes that these bridges are much better and better proportioned throughout than bridges designed for this same loading with a specified factor of safety of four taken in the ordinary way.—**W. J. Watson,** *Proc. C. E. Cleveland, Rept. Rlrd. Gaz., Vol. XXXV, No. 48,* pp, 854-855.

The Breakwater at Buffalo, New York.

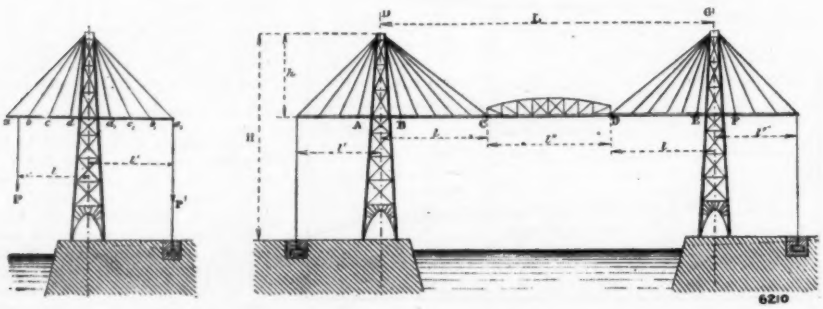
THIS paper gives a lengthy and detailed description of the construction of the Buffalo Breakwater, situated at the foot of Lake Erie, and particulars of the damage done by storms during several years. The final completion of the stone section of the breakwater in 1903 forged the last link in the chain of a system of harbour protection that is without parallel in the United States. This structure is the extension to Stony Point which has been building since 1897. The paper is accompanied by numerous tables, photographs and drawings illustrating the progress of the work.—**E. Low,** *Proc. Amer. Soc. C. E., Vol. XXIX, No. 9,* pp. 948-1072.

Borings for the Bohio Dam, Panama Canal.

IN this paper the author first gives the reasons for choosing the village of Bohio as a site for the dam, describing how various boring parties were sent to the Isthmus, and the results of their investigations. He then describes in detail the methods of carrying out the different borings. At one part a deep buried channel was encountered, the limits of which are shown on a plan which accompanies the paper. The valley was divided up into 12 sections, indicated on the plan; the work done in two sections is described in detail, and a table is given showing the holes drilled, the depth, and the approximate amounts of impervious and permeable materials and soft rock for each hole. In an appendix the author gives a list of parts of the drill outfit used on the Panama Canal borings. The paper is illustrated by numerous photographic views showing the progress of the work.—**R. C. Smith,** *Jnl. Westn. Soc. Eng., Vol. VIII, No. 4,* pp. 372-399.

A Novel Transporter Bridge.

THE ordinary type of transporter bridge with parabolic cables requires very massive masonry anchorages, of which the cube is in proportion to the dimensions of the work, to the weight of the car, and the weights which it will have to carry. At Nantes the cost of ordinary anchorages would have been prohibitive, and some alternative had to be devised. The problem was to cross a waterway of 141 m. without using massive anchorages, which would necessarily have been placed at more than 25 m. behind the axis of the towers. The simple solution arrived at is based on the following principle. Given a metal tower, if from each side we suspend by cables two parts of a platform, *abcd*, $a_1 b_1 c_1 d_1$, of equal weight and dimensions, we have a balanced system (Fig. 1). If we assume the part *abcd* of the platform to be loaded with a weight P, placed at a distance l from the axis of the tower, we must, to keep the system balanced, place on a_1 a weight P' such that $P' = \frac{Pl}{l'}$, l' being the distance from the point a to the axis of the tower. Instead of this weight P' we can fix the point a_1 by vertical cables to a masonry anchorage under the ground, the dimensions of which must be such that the weight shall be more than, or at least equal to, P'. It is evident that the tower, under the action of the dead and live loads, has only to withstand vertical compression. Thus, to cross a given waterway L, we have to make a judicious choice, appropriate to the local conditions, of the lengths l, l_1, and l'', which constitute the outer and inner parts of the platform and the central parabolic girder (Fig. 2). The first application of this system was made in the

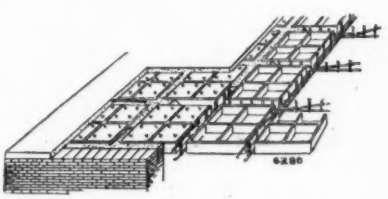


A NOVEL TRANSPORTER BRIDGE.

transporter bridge at Nantes, the principal dimensions of which are (see Fig. 2)—$L = 140{\cdot}996$ m. ; $l = 58{\cdot}188$ m. ; $l' = 25{\cdot}00$ m. ; $l'' = 34{\cdot}620$ m. ; $H = 75{\cdot}650$ m. ; $h = 31{\cdot}400$ m. The platform, which is one of the most interesting parts of the work, consists of two girders of *I*-section placed 8 m. apart. The car, which is 10 m. long by 12 m. wide, is suspended by thirty cables, ten of which are hung diagonally, so as to steady the car during high winds. The cables are suspended from a trolley 32 m. long, which travels along the overhead track, motion being communicated by means of a cable which is alternately wound and unwound on the drum of an electrically driven crab, the operation of which is controlled by the attendant on the car. —**G. L. Le Coco,** *Gén. Civil, Vol. XLIV, No. 4,* pp. 49–55.

Concrete-Steel at the New Concert Hall, Strasburg.

In the construction of this building, which is not merely a concert-room but a complete casino, a liberal use has been made of concrete-steel, on the Hennebique system. This material is specially suitable for buildings where considerable spaces have to be spanned without intermediate support, and in which it is necessary to take elaborate pre-



CONCRETE STEEL.

cautions against fire. The grand concert hall at Strasburg includes a nave 13 m. high, with a floor area of 32·50 m. by 19·85 m. without the stage, and two aisles measuring 18·40 m. by 3·40 m. The springings of the ceiling are supported by groups of columns, and the side aisles are divided in their height by a ramped floor, with a balcony projecting 2 m. into the hall. The stage measures 12·60 m. by 9 m. The chief difficulty experienced by the constructional engineers arose from the fact that, owing to the exigencies of architectural design, the walls and partitions on the different stories were not situated one above another. Hence it became necessary to construct each floor as an enormous slab capable of supporting the weight of the upper stories at any given point. For such a purpose concrete-steel construction is particularly suited, owing to its solidarity and the perfect continuity between all constituent parts and members. Further, by the employment of concrete-steel in the manner mentioned, it became possible to ensure the equal distribution of the floor-loads over the entire horizontal section of the supporting walls. In a series of tests made in May, 1902, on various sections of these floors, differing widely in shape and length, loads of from 400 kg. to 500 kg. per sq. m. caused a maximum deflection of less than 2 mm. The figure here reproduced illustrates the Züblin system of hollow-panel floor construction adopted in some parts of the concert hall. Economy is mentioned by the writer as one of the great advantages of concrete-steel construction, but rapidity of execution is an important element. The building described was erected, at a cost of about £30,000, in a little more than twelve months. —**G. Espitallier,** *Gén. Civil, Vol. XLIV, No. 11,* pp. 169–170.

The Underpinning of Sub-Surface Railways at Paris.

In this paper the author gives an account of the underpinning of sub surface railways of Paris. He explains how the difficulty of this work was increased by the old quarries with which the city is undermined. Having briefly discussed the geology of Paris, the author gives an account of the methods adopted for dealing with the limestone and gypsum which was encountered in some of the quarries, and considers at some length the underpinning necessary in connection with the foundations for the Trocadero-Étoile line, and the South Circle Railway, No. 2. Having described the methods of underpinning employed when the quarries were in good or bad condition, the paper concludes with a summary of the operations conducted. The article is illustrated by numerous drawings of cross and longitudinal sections of the work, together with photographic views of subterranean cavities in different parts of the city.—**M. Wickersheimer** and **M. Weiss,** *Pub. Works, Vol. II, No. 1,* pp. 61–74.

Spherical and Framed Domes.

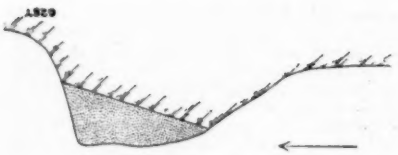
In this paper the author presents what he believes to be original information on a subject regarding which little or nothing has appeared in American engineering literature. He sets out plainly the relations between the principal stresses in domes and their magnitude, and demonstrates a simple and rational method of framed-dome construction. While this paper does not cover all that could be said on the subject of domes, it gives enough to enable the designer to handle ordinary problems with confidence. In this respect the author believes he is the first to suggest a method of arranging the stone coursing of masonry domes so as to do away with the defects experienced in the past, and to give a new impetus for the execution of domes in architectural and engineering design where they have been avoided, not so much because of cost, but because their stability has been distrusted. This lack of confidence, the writer believes, need not be felt if domed structures are designed in accordance with the methods proposed in his paper.—**E. Schmitt,** *Am.Soc.C.E., Vol. XXIX, No. 10,* pp. 1100–1143.

Practical Design of Steel-Concrete Structures.

THE object of this paper is to epitomise the subject so far as its application to certain railway structures is concerned. The author says that during the earlier development of steel-concrete construction it was supposed that the thermic expansion of concrete was identical with that of steel, and the prevention of temperature cracks by metal reinforcement was on that basis easily explained. Later researches, however, have shown that the coefficient of expansion of concrete is 0·0000055, while that of steel is 0·0000065 per deg. Fahr. change of temperature, or 15 per cent. less for concrete than for steel. It has been shown by M. Considère that a properly reinforced concrete beam under tensile stress will sustain an elongation of more than 1 in 1,000 without rupture, while plain concrete will fall under an elongation of less than 1 in 10,000. That the ability of reinforced concrete to sustain an elongation from 10 to 15 times greater than ordinary concrete cannot now be doubted, and the most plausible explanation of the phenomenon which has been advanced is that in plain concrete the elongation occurs in the section of least resistance, which becomes the point of rupture, whereas in reinforced concrete the metal distributes the elongation uniformly throughout the mass. It is necessary that in providing metal reinforcement the allowable working stress be based upon the elastic limit and not upon the ultimate strength, and consequently it is desirable that the elastic limit be high. The author then deals with temperature cracks, adhesion between concrete and steel; then passing on to the construction of culverts, walls, piers, and other structures, of which he gives numerous detailed drawings.—**W. W. Colpitts,** *Asst. Chf. Engr. K.C.M. & O. Rly., Rly. Age, Vol. XXXVII, No. 2,* pp. 44–52.

Dredging Channels through River Bars.

THE improvement of rivers by dredging is now being done on a large scale in Russia. From a general point of view the routine business of the dredging craft on rivers consists in creating an easy and deep waterway for boats, and in deepening entrances and areas of river harbours and refuges, all of which must be accomplished at a small cost. To obtain this result, two things must be taken into consideration—(1) the dredging fleet must be equipped and manœuvred with care, and (2) the durability of the improvement obtained by dredging must not be lost sight of. It is important to find such a shape for the channel to be cut as will not only prevent any filling up, but insure its maintenance and even its scouring and deepening. The dredge cuts on the Volga are now made as channels of constant width (250 ft. to 260 ft.), and the depth of dropping the ladder remains constant during the whole of the operations; but the writer thinks that cuts made with a continuous raising of the ladder are generally durable enough. He is also of opinion that it is desirable to obtain a downward slope, as Fig. 1, in the direction of the current on the bottom of a dredged channel, as the water then has to exert much less force in pushing drifts down the



DREDGING CHANNELS.

inclined plane. Further, a dredged channel should be commenced narrow, and, according to the rate of progress of erosion, the width of the dredged cut should be increased, going up stream, so that the funnel-shaped opening of the channel into which the water is entering shall be constantly turned against the current. Briefly, the basis of the proposed method is the supposition that, owing to the shape recommended, the progress of the suspended material in a dredged channel will be the easier. This suspended material, and the material excavated from the channel itself, will pass without hindrance to the deep water below, and the channel will be durable and possibly even deepened by scour. Furthermore, on account of forced erosion in the direction of the dredged cut, there will be a constant reduction in the amount of cutting necessary, and the estimated total length of the cut will be reduced. One important feature is that during the operations the axis of the channel must make as acute an angle as possible, with the mean direction of the current through the bar. Should the dredged channel be traced so that the current erodes only one side of the cut, and causes drift to form on the other, no sure method of preventing the channel from filling up can be indicated. —**S. Maximoff,** *Trans. Am. Soc. C. E., Vol. XXIX, No. 8,* pp. 868, 878.

An Ingenious Method of Handling I-Beams.

SOME long and heavy I-beams were recently handled by an ingenious method in New York, where it was necessary to fix a set of five 18-in. I-beams 24 ft. long on the side walls in the third storey of a store. The beams could not be hoisted through the stair wells nor on the elevator cars, and as the side walls were only about 22 ft. apart, additional difficulty was presented in getting the beams in position. Recesses were cut in the brickwork to receive the bearing plates, and in one wall these were cut entirely through. The elevator was lowered to the foot of the shaft, and the counter-weight rope and the two hoist ropes attached to it were lashed together near the lower ends. A tackle was attached to the lashing, and operated to relieve the stress on the bolts which connected the ropes to the car. These bolts were then removed, and a steel plate was bolted to the ends of the rope. A hook and clevis was connected to the lower edge of the plate. The I-beams were separately delivered from the street to the first-storey floor, and slings attached to them near the centre of gravity were engaged by the hook on the elevator ropes. The elevator machinery was then operated to lift each beam up the shaft, the

lower end being guided by a tag line. At the third storey the upper end of the beam was depressed, and passed through an opening made by removing the sash of an adjacent window. The beam was then lowered to a horizontal position and rolled across the floor. One end of it was inserted in the opening through the wall, and the beam was pushed through until the other end could be inserted in the recess in the opposite wall, where it was seated in the final position, and both openings were bricked up. All the beams were similarly set in a rapid and economical manner, after which the clevis plate was removed, and the elevator ropes were re-attached to the car.—**Anon.,** *Eng. Rec., Vol. XLIX, No. 1,* p. 53.

METALLURGY.

Metallurgy of Homestake Ore.

In a paper read before the American Mining Congress, the author describes the methods employed by the Homestake Mining Co. for the extraction of gold from a horneblende, garnetiferous schist which has been crushed and infiltrated with free silica and pyrites. The processes of milling, classification and cyanidation, are described and illustrated. The effluent from the cyanide tank is run into a weak precipitating tank—the solution having a strength of 0·1 of 1 per cent. *KCn*. The capacity of this tank is equal to 300 tons of solution. The solution is agitated by means of compressed air; during the agitation about 60 lbs. of zinc powder, in the form of an emulsion, is sprayed in. The mixture is then pumped through two large filter presses of the flush-plate and distance-frame pattern, containing 24 frames, each 4 inches in depth. The gold, silver and excess of zinc remain in the frames and on the cloth, whilst the barren solution passes through into storage tanks below. The value of the solution having been reduced by this filtration from 2 dols. to 5 or 10 cents per ton—being a precipitation of 95 to 97·5 per cent. This efficiency lies largely in the fact that the cloths of the presses are coated with about $\frac{1}{8}$ in. of powdered zinc and precipitate, and therefore, every particle of the solution comes into contact with the fine zinc. The precipitate, after removal from the filter presses, is treated first with dilute hydrochloric acid in a lead-lined mixing tank fitted with a mechanical agitator. After agitation and settling, the supernatent liquid is forced through a filter press by air pressure. Sulphuric acid is then added, the mixture heated, agitated, allowed to settle, and the supernatent liquid passed through the press as before. Wash water is added to the tank, and the whole mixture put into the press and washed. The precipitate is removed to a steam dryer and partially dried; it is then mixed with litharge, borax, silica and powdered coke. The mixture is sprinkled with a solution of lead acetate, and the mass briquetted under a pressure of 4,000 to 6,000 lbs. per. sq. in. The dried briquettes on cupellation fuse quietly and quickly at a low heat with no dust or volatilisation losses. The lead absorbs the values sinking to the bottom, the slag having been tapped off, the lead is cupelled off as litharge, and the resultant metal—975 to 985 fine—is ready to run into bars. —**C. W. Merrill,** *"Mines and Minerals," Vol. XXIV, No. 5,* pp. 233-236. —*P.L.*

Estimating the value of Coke for Foundry Use.

The writer gives the following as a standard for foundry coke: Carbon, 94 per cent.; water, 1 per cent.; sulphur, 0·5 per cent.; ash, 4·5 per cent.; and fixes the value of such a coke at 40s. per ton.—**W. J. May,** *Pract. Eng., Vol. XXVIII, No. 875,* p. 542.—*P. L.*

The Effect of Impurities on Commercial Copper.

The influence of single impurities on pure copper may be divided into three groups, according to their effect on the microstructure. *1st Group:*—Metals which separate out round the copper crystals in the free state, such as lead and bismuth. *2nd Group:*—Metals which alloy with a portion of the copper and separate out round the crystals as an alloy, such as arsenic, antimony, tin, zinc, and the non-metals oxygen, phosphorus and sulphur. This group may be further sub-divided into two divisions, according as to whether the alloy separates into two constituents after solidification or not:—(*a*) Antimony, zinc, and oxygen alloys separate into two constituents; (*b*) Arsenic, phosphorus, and tin separate out round the crystals of copper as a single alloy, or as a solid solution of arsenic, tin, and phosphorus in copper, in which two micro-constituents cannot be detected. Sulphur separates out as cuprous sulphide. *Third Group:*—Metals which dissolve in the copper crystals, and do not separate on solidification, such as iron, manganese, aluminium, and nickel. Pure copper under the microscope shows a series of crystals having fine, sharp bordering lines. The same copper alloyed with 0·2 per cent. of lead or bismuth shows the crystals surrounded with a thin skin of lead or bismuth. Traces of these two metals present in copper are sufficient to impair its rolling properties, and even 0·002 per cent. bismuth added to molten electrolytic copper, containing no Cu_2O, will render it brittle. Copper containing 0·2 per cent. arsenic, phosphorus, or tin microscopically consists of a series of copper crystals, each one being surrounded by a network incapable of resolution into two constituents. Copper containing 0·2 per cent. of any of the last three elements will permit of hot rolling, and is very malleable. Copper containing 0·2 antimony, zinc, or oxygen shows a network embracing the copper crystals, and this network may be seen to contain two constituents. The presence of this amount of any of these elements is injurious, and copper so contaminated cracks on the edges during rolling. One per cent. of Cu_2O may be present in commercial copper without influencing its malleability, provided no other impurities are present. In a series of experiments as to the influence of impurities on rolling properties the following results were obtained:—

No.	Impurity Added.	Rolling Test.	Bending Test (Annealed).
1	0·1 % lead	Cracks at edges	Bends fairly well, but cracks along bend.
2	0·1 % bismuth	Cracks very badly at edge .	Will not bend, but cracks off short.
3	0·1 % antimony	Cracks at edge	Bends fairly well, but cracks along bend.
4	0·1 % zinc	Cracks at edge	Bends poorly.
5	0·1 % sulphur..	Cracks badly	Bends badly.
6	0·6 % arsenic and 0·1 % lead ...	Slightly cracked at edges ..	Bends well, with no cracks.
7	0·6 % arsenic and 0·1 % bismuth ...	Cracks at edge, but not so badly as without the arsenic	Bends fairly well.
8	0·6 % arsenic and 0·05 % bismuth ...	Rolls fairly well	Bends well.
9	0·6 % arsenic and 0·1 % antimony ...	Cracks at edge	Bends well.
10	0·6 % arsenic and 0·1 % zinc ...	Rolls fairly well	Bends fairly.
11	0·6 % arsenic and 0·1 % sulphur ...	Rolls fairly well	Bends fair.
12	0·5 % tin and 0·05 % bismuth ...	Will not roll	——
13	0·5 % tin and 0·1 % lead	Will not roll	——
14	0·5 % manganese and 0·05 % bismuth	Will not roll	——
15	0·5 % manganese and 0·1 % lead . .	Rolls badly	——
16	0·5 % manganese and 0·1 % sulphur .	Rolls well	Bends well.
17	0·5 % aluminium and 0·05 % bismuth	Will not roll	——
18	0·5 % aluminium and 0·1 % lead ...	Will not roll	——
19	0·5 % aluminium and 0·1 % sulphur .	Rolls fairly	Bends well.

These results show that arsenic has, to some extent, the property of neutralising the injurious effect of bismuth, lead, and antimony, and that tin, manganese, and aluminium intensify the effect of these impurities.—**Ernest A. Lewis, F.C.S.,** *Engineering, Vol. LXXVI, No. 1979,* pp. 753–754.—*P. L.*

A Problem on the Metallurgy of Cast-iron.

THE presence of dissolved oxide of iron in pig-iron and scrap is one of the greatest and perhaps the least realised of foundry difficulties. In the case of molten steel, this oxide of iron is readily removed by the addition of manganese; but with molten pig-iron the temperature is far too low for the reaction between oxygen and manganese to take place. Aluminium effectually removes oxygen, and in high silicon irons there is no objection to its use; but for irons low in silicon aluminium may only be used in small amounts, as it promotes the formation of graphite, which is fatal to much of the work for which these irons are used. Experiments made by Mr. Rossi in the author's foundry have shown titanium to be an excellent deoxidiser for cast-iron—an addition of 0·2 per cent. titanium resulting in an increase of 20 per cent. in the mechanical properties, and as the titanium was oxidised, the composition of the metal was unaltered. The author, in conclusion, draws attention to this problem of oxygen in cast-iron, and the important results likely to follow from its careful investigation.—**Dr. R. Moldenke,** *The Iron and Steel Metallurgist, Vol. VII, No. 1,* pp. 26–29.—*P. L.*

The Molecular Mobility of Cast-Iron.

EXPERIMENTS conducted by Mr. A. E. Outerbridge have shown that not only is the strength of cast-iron reduced by repeated reheating but that the dimensions of the pieces are materially increased. Thus a bar of cast-iron 1 in. by 1 in. by 14·8 ins. heated and cooled 23 times increased in length an inch, the increase in transverse dimensions being $\frac{1}{8}$ of an inch. Ultimately this bar was heated and cooled in air 35 times, resulting in an extension of 1·374 ins. A further feature lies in the reduction of the specific gravity by this treatment: a bar having a density of 7·13 after 16 heatings and coolings yielded a specific gravity of 6·86. In other words the untreated metal weighed 16·8 lbs. per cub. ft. more than the treated metal. Prolonged heating without cooling does not appear to produce the foregoing results. In heating, the higher the temperature reached, short of fusion, the greater the permanent expansion of the cold bar; and it has been found that bars heated to a temperature of 1,500 degs. Fahr. show an expansion twice as great as that obtained from

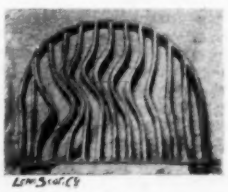


FIG. 1.

FIG. 2.

THE MOLECULAR MOBILITY OF CAST-IRON.

similar bars heated to 1,200 degs. Fahr. Chemical examination of the treated bars shows that the only change occurring is that of combined carbon into graphitic carbon. This expansion of cast-iron due to repeated heating and cooling is well shown in the accompanying illustration, in which Fig. 2 represents the pattern from which Fig. 1 was made. Fig. 1, when fixed in position, had its outside frame protected from the direct heat of the fire and consequently increased very little in size. The bars of the grating were exposed to the direct rays of the fire, and owing to the repeated heating and cooling were distorted owing to their inability to expand freely in the unaffected frame. Similar experiments conducted on wrought-iron and steel have failed to yield any increase in length, but a slight contraction has been observed. This apparent contraction amounts to only 0·03 in. in the case of wrought-iron and to 0·05 in. in the case of steel after 41 heatings and coolings. A bar of bronze after 17 heatings and coolings showed an apparent increase of 0·01 in. which may have been due to oxide on the ends.—**Anon,** *Engineering, Vol. LXXVII, No. 1984,* pp. 56–57.—*P.L.*

Alloys used in Foundry Practice.

THE antiquity and growth of the bronze industry is indicated. Modern alloys are grouped into six classes, the first of which, brasses, is considered in the present article. A series of typical compositions are given and the influence of an increasing content of zinc on the colour of the alloys is shown. The mechanical properties are shown in the following table and for comparative purposes values obtained from copper and zinc cast in sand are also included :—

Alloy.	Composition.		Specific Gravity.	Tenacity in Tons per sq. in.	Extension % on 2″.	Contraction of area %
	Copper.	Zinc.				
Zinc cast in sand	—	—	7·3	1·5	—	—
Copper ,, ,, ...	—	—	8·8	9·0	11·0	—
Red Brass cast in sand	89·6	10·2	8·55	12·6	26·0	30·0
Yellow Brass ,, ,, ...	73·0	26·0	8·10	13 0	43·0	35·0
Muntz Metal ,, ,, ...	59·0	40·0	8·03	19·0	15·0	16·0

Percy Longmuir, *The Foundry Trade Journal, Vol. V, No. 25,* pp. 3–8.—*P.L.*

Notes on Cupolas and Cast-Iron.

THE author deals with varieties of cupola practice, giving analyses of cupola coke, and collating the results of various English and American experiments on cast-iron. In experiments on the melting loss, it was found that rusty scrap melted alone gave a loss of 14 per cent., whilst the loss from good machinery scrap varied from 5 to 7 per cent. Mixtures of soft iron gave a loss of 4·87 per cent., whilst that obtained from hard cylinder mixtures varied from 2·5 to 3·6 per cent.—**C. Morehead,** *Paper read before the Rugby Engineering Society, Jan. 21st, 1904.*—*P. L.*

By-product Oven Gas and Tar as Fuels for the Open-Hearth Furnace.

A PRELIMINARY trial with by-product oven-gas proved that the furnace could not be commercially worked with this fuel alone, but with tar as an auxiliary no difficulty was found in maintaining the requisite temperature. Results obtained in the manufacture of 22,000 tons of steel with coke-oven gas and tar, in comparison with a similar quantity made with producer-gas, show that in each case the following amounts of fuel were required per ton of steel made: (1) 17,127 cub. ft. oven gas and 584·2 lbs. of tar; (2) 1,076 lbs. of coal. With coke-oven gas and tar, 39·4 per cent. less sulphur was introduced than when producer-gas alone was used, and if tar only was to be used 78·4 per cent. less sulphur would be introduced. From the point of economy the use of tar does not commend itself at present prices; but with an increase in the number of by-product oven-plants the price may be lowered sufficiently to make its use an economy, as well as a convenience, in the open-hearth furnace.—**David Baker,** *Iron and Steel Metallst., Vol. VII, No. 1,* pp. 21–26.—*P. L.*

Side-Blown Steel Converters.

IN this paper, read before The Foundrymen's Association of Philadelphia, the author deals with various types of surface-blown converters. It is generally conceded that the superheated steel made in side-blown converters cannot compete with open-hearth or bottom-blown Bessemer steel for heavy castings or ingots. However, for the production of castings of light weight or thin section this type of converter occupies a field of its own and, further, extremely mild steels for electrical castings may be produced by it. The permeability and hysteresis curves from the latter type of steel approach those obtained from Swedish iron, whilst in composition they average carbon 0·10 per cent., manganese 0·04 per cent., silicon 0·02 per cent., and phosphorus 0·04 per cent. For ordinary castings the average content of carbon is 0·25 per cent. The uniformity of the process is shown in the following series of carbons obtained from consecutive and not selected charges:—Open-hearth steel, Newark, N.J., carbon, 0·31, 0·26, 0·21, 0·26, 0·33, 0·40, 0·41, 0·41; side-

blown steel, St. Paul, Minn., 0·27, 0·28, 0·26, 0·28, 0·24, 0·24, 0·24, 0·25.—**N. Lilienberg,** *The Iron Trade Rev., Vol. XXXVII, No. 2,* pp. 37-42.—*P. L.*

Some Applications of the Theory of Electrolysis to the Separation of Metals from one another.

THE only principle hitherto involved in electrolytic separations has been based on the method of successive potentials, each metal depositing at the potential proper to that metal. In practice this principle has only been applied to metals (copper and silver, silver and bismuth, mercury and bismuth) whose polarisation potentials are lower than that of hydrogen. Metals whose polarisation potentials are higher than that of hydrogen cannot be separated by gradual increase of the e.m.f., on account of the extremely small fraction of the current then used to precipitate the metal, hydrogen ions carrying most of the current. The author has therefore made use of three other applications of the theory of electrolysis: I. *Reduction of the Resistance of the Bath by Suppressing the Formation of Gas at the Anode.*—The current may thus be increased in two ways—(1) By suppressing the liberation of oxygen at the anode. To effect this a reducing agent, such as sulphurous acid, may be introduced. The same potential will then greatly augment the current and hasten precipitation. The method has been successfully applied to separate nickel from zinc. (2) By the use of soluble anodes. The anode must replace in the solution the metal that is to be separated, and that only, and it must be immersed in the solution of an indifferent salt, a membrane separating the anolyte and catholyte. Obviously an external source of electricity is unnecessary. The nickel zinc separation is again given as an example, the operation being described in detail. In this case there is a limit to the relative quantities of zinc and nickel that can be separated. For by Nernst's formula $e = \frac{k}{v} \log \frac{P}{C} - \frac{k}{v'} \log \frac{P'}{C'}$, where e is the e.m.f. between the metals, k a constant for a definite temperature, v and v' the valencies, and C and C' the concentrations of the precipitating and precipitated metals, when the concentration C of the zinc in the inner cell increases, e will diminish. There must not, therefore, be too much nickel to deposit. The phenomenon is complicated by secondary reactions which must be taken into account in the cases of other separations, such as concentration e.m.f.'s, increase of e.m.f. due to local action, and migration. These are discussed fully in the paper. II. *Influence of the Nature of the Cathode.*—By suitably choosing the metal for the cathode, the liberation of hydrogen may be completely avoided, and the conductivity may be so much increased that the separation of the metals becomes possible. The division of metals into two groups, which can and cannot be deposited from strongly acid solutions, has for its basis the position occupied by hydrogen in the polarisation potentials of the metals. But this, as Caspari has shown, varies with the metal of the cathode. Hence by suitably altering that metal, metals can be made to pass from one group to the other, and thus separations impossible with a platinum cathode may be effected. The separation of zinc and cadmium (impossible on a platinum cathode) is given as an example. Platinum gauze covered electrolytically with tin and cadmium forms the cathode. III. *Formation of Complex Salts.*—Metals may be prevented from precipitating by causing them to form complex salts, which dissociate to give not the metallic ions, but complex ions containing the metal. As an example, the separation of antimony and tin in a solution of sodium hydrogen sulphide is described.—**M. Hollard,** *Proc. Faraday Soc., Feb. 1904.*

The Action of Radium, Röntgen Rays, and Ultra-violet Light on Minerals.

THE authors, in a memoir submitted to the New York Academy of Sciences, describe an extensive series of investigations as to the conduct of minerals under the influence of Röntgen rays, ultra-violet light, and emanations of radium preparations. From these observations it is concluded that two properties are recognisable in minerals—radio-activity and a property which responds to that activity. These two properties may be further divided into minor divisions as follows: (1) Minerals that respond to the radio-active bodies; (2) minerals that do not respond; (3) minerals that respond to ultra-violet rays; (4) minerals that respond to Röntgen rays; (5) minerals that will not respond to either one, two, or all of the three forms. In conclusion the authors state that as the electric furnace has given a series of absolutely new carbides, as the production of low temperatures has resulted in the liquefaction of all known gases and assisted in the discovery of new ones, so perhaps the application of these newer forms of energy may give rise to the means of identifying substances that have escaped earlier observation.—**G. F. Kunz, Ph.D., A.M.,** and **C. Baskerville, Ph.D.,** *Chemical News, Vol. LXXXIX, No. 2,301,* pp. 1-6.—*P. L.*

Strength of Steel Castings at Ordinary and Higher Temperatures.

THE experiments described in this paper were undertaken to ascertain the dependency of the mechanical strength of steel castings on temperature; they are relative to castings from three different works and are distinguished by the letters *O*, *K* and *M* respectively. It is shown in the first place that the average tensile strengths will increase up to about 300 degs. Cent.; the author does not note any appreciable influence of the duration of the load. For higher temperatures on the other hand, the mean tensile strengths are found to increase, viz., for loads lasting about half an hour:—For casting *O* from 4,788 (300 degs. Cent.) down to 2,691 kg.-sq.-cm. (500 degs. Cent.); *K* from 4,242 to 2,043 kg.-sq.-cm.; *M* from 4,319 to 2,274 kg.-sq.-cm. For more prolonged loads (about 8 hrs. to 12 hrs.), there is a decrease in the tensile strength, namely, at 500 degs. Cent.:—For casting *K* from 2,043 down to 1,561 kg.-sq.-cm.; *M* from 2,274 to 1,911 kg.-sq.-cm. As regards, on the other hand, the individual values for the tensile strength, there

are, in the case of casting *O*, the lowest departures at ordinary temperatures and the highest departures at 300 degs., whereas in the case of *K* and *M*, 100 degs. and 20 degs. respectively will correspond with the minimum departures, and 200 degs. and 100 degs. with the highest departures. The average fracture tensions are found to decrease in the case of casting *O* from 25·5 (20 degs. Cent.) down to 7·7 per cent. (200 degs. Cent.); *K* from 29·0 to 17·7 per cent.; *M* from 27·2 to 15·2 per cent. For temperatures upwards of 200 degs., the average fracture tension will augment again up to 33·3, 51·3, and 26·1 per cent. respectively at the temperature of 500 degs. Prolonged loads will result in the tension being lowered at 300 and 400 degs. and augmented at the temperature of 500 degs. The individual values for the fracture tensions show departures among one another, which augment in some cases at extraordinary rates, for increasing temperatures. The average contractions of the cross-section are found to decrease up to 300 degs., this decrease being:—For casting *O* from 50·4 (20 degs. Cent.) down to 15·8 per. cent. (300 degs. Cent.); *K* from 56·1 to 49·4 per cent.; *M* from 48·7 to 34·7 per cent. At higher temperatures there is once more an increase, values as high as 44·6, 75·7 and 42·1 respectively being noted at the temperature of 500 degs. There is, moreover, an influence of a prolongation of the load. The departures noted between the individual values are rather high. From the above it is inferred that a steel casting, while appearing to be a very satisfactory and fairly uniform material with respect to its tenacity at ordinary temperatures, may present little tenacity and uniformity at high temperatures. This behaviour should have an important bearing on the construction of steam boilers, etc., where the strength corresponding to ordinary temperatures is less important than that corresponding to higher temperatures.—**C. Bach,** *Zeitsch. Vers. Deutsch. Ing., Vol. XLVII, Nos. 49, 50,* pp. 1,762–1,770 and 1,805–1,812.—*A. G.*

Casting Ring Pulleys.

THE writer recommends the use of a plain rim, about 12 ins. deep, and varying in thickness according to the diameter of the pulley, in place of the ordinary pattern. The method of moulding is as follows: The rim is bedded in the floor to the required depth, levelled, and the outside rammed up. The inside is then partly rammed, and a bed struck of the proper height to take the arm cores. The arm cores are placed in position and weighted down. The hub of the pulley is formed by the inner ends of the arm cores, the central core is placed in position, and the top of the hub covered with a core through which holes are arranged for the gate pins. The gate pins are fastened in position, and the inside of the mould rammed up, the rim being drawn to form the required width of face. The rim is usually drawn 2 ins. higher than the finished pulley to allow for an overflow, and also for sufficient metal to face the edge in the lathe. No copes, gaggers, or stock patterns are required, and it is stated that two 4-ft. pulleys, each having a face depth of 14 ins., have been moulded and cast in 7½ hrs. by one man.—**Harry Willis,** *Foundry, Vol. XXIII, No. 4,* pp. 175–176.—*P. L.*

Some Cupola Practice.

IN any consideration of melting ratios the writer draws attention to the necessity of considering the character of the castings for which the metal is melted. A better ratio is possible in a foundry producing heavy castings, than in one engaged exclusively in the production of light and intricate castings. A series of actual ratios obtained from eight typical foundries in a New England state are as follows: (1) 7·86 of iron to 1 of coke; (2) 6·26 to 1; (3) 8·72 to 1; (4) 8·89 to 1; (5) 7 to 1; (6) 6·82 to 1; (7) 6·55 to 1; (8) 9·15 to 1.—**R. H. Palmer,** *Foundry, Vol. XXIII, No. 4,* pp. 171–175.—*P. L.*

Notes on the Welding of Aluminium.

THE author commenced his paper by stating that soldered aluminium joints have proved unsatisfactory, as they will not stand the test of time, because galvanic action takes place between the aluminium and solder. One of the chief difficulties encountered other than the formation of oxide in soldering aluminium is, that a few degrees below its welding-point it passes into a pasty or brittle state, and being a very good conductor of heat, the solder very rapidly cools and freezes before it has time to flow sufficiently. He then proceeded to describe Dick's machine for welding aluminium by the removal of the oxide mechanically, combined with pressure. Reference was also made to Heraeus's process of welding aluminium, which consists in heating the aluminium in a reducing atmosphere until it reaches the pasty stage, when the joint is made by kneading and hammering. Emmé's process, which is somewhat similar, consists in heating the aluminium up to 600 degs. Cent., and welding by hammering. The electric welding of aluminium has not proved commercially successful. A description was given of Schmidt's electric welding apparatus, which consists of a carbon stick, which is used in much the same way as a soldering iron, by being moved over the portion to be welded to remove the oxide, the aluminium forming one electrode, the carbon stick the other electrode. Jones's machine for welding aluminium tubes was also illustrated: a strip of aluminium is wrapped round a mandrel, and the joints are fixed together by passing a low-tension current through the portions to be welded. The author then went on to describe his own process, which requires no flux or solder, and does not necessitate the hammering of the joint when in the pasty state, the process being especially suitable for wire, rods, and tubes. The machine employed is fitted with clamping screws, which are controlled by levers. The aluminium is heated by a benzine lamp, and when raised to the point of fusion pressure is applied to the levers, which causes the aluminium to be welded to unite, a ring of metal being squeezed out. This ring, which is largely composed of oxide, acts as an insulating and supporting collar, the molten metal being retained within it. Water is then projected on to the joint by turning a handle; at the same time a screen is moved in front of the flame. The rod is then

removed, and when the collar is filed off the joint will be found to be as strong as the rest of the metal. A table was given showing the tensile strength of 12 consecutive welds; in all the tests the specimen broke at some distance from the weld, and in no case did it actually break through the weld. Illustrations were given demonstrating how molten aluminium can be encased in a shell of aluminium oxide.—**S. O. Cowper-Coles,** *Proc. Faraday Soc., Feb. 1904.*

Silicon Steels.

THIS research embraces a very complete investigation of various alloys of iron and silicon. Two series of steels were prepared, one containing about 0·2 per cent. and the other about 0·8 per cent. of carbon. In each series the silicon varied from nothing to about 30 per cent. The actual contents of carbon and silicon are as follows:—

First Series.		Second Series.	
Carbon.	Silicon.	Carbon.	Silicon.
0·208	0·409	0·878	0·433
0·209	0·932	0·835	1·156
0·117	1·600	0·968	2·090
0·277	5·120	0·944	5·540
0·216	7·170	0·808	7·310
0·326	9·740	0·718	9·100
0·350	13·900	1·036	14·100
0·188	19·800	0·539	20·270
0·277	25·500	0·431	26·800
0·249	29·100		

Steels of the first series exceeding 7 per cent. silicon would not roll whilst a content of 5 per cent. silicon and 0·9 per cent. carbon represents the forging limit of the second series. From a micrographic study of the first series the author suggests a classification as follows:—(1) Steels showing a pearlitic structure and containing from nothing to 5 per cent. silicon. (2) Steels showing a special structure and containing more than 5 per cent. silicon. This latter group may be sub-divided as follows:—*A.* Steels showing pearlite and graphite, these contain from 5 to 7 per cent. silicon. *B.* Steels containing the silicon in solution and the carbon entirely in the form of graphite. *C.* Steels containing a definite compound of silicon and iron and the carbon in the form of graphite. These steels contain more than 20 per cent. of silicon. A micrographic examination of the second series gives similar divisions. It is necessary then to conclude that only the content of silicon has an influence on the constitution of these steels and that the carbon has none. From a chemical study of the alloys it is concluded that silicon may exist in four states according to the amount present:—(1) In a state of solution in iron. (2) Fe_3Si. (3) Fe Si. (4) $Fe Si_2$. The experiments on annealing show that silicon steels annealed at a temperature of 950 degs. C. are affected in a similar manner to ordinary carbon steels, but if the annealing time is prolonged or the temperature raised the carbon is deposited as graphite:—(1) The higher the content of silicon the lower the temperature at which graphite commences to separate. (2) The separation of graphite once commenced continues at temperatures lower than that at which the reaction started. Quenching experiments shows that silicon steels possessing a pearlitic structure undergo the same transformation as ordinary carbon steels, but silicon steels containing graphite appear to undergo no transformation by quenching. Only those steels which permitted of rolling were tested mechanically, and the results obtained from the first series are given in the following table:

Carbon.	Silicon.	Elastic Limit.	Tenacity.	Elongation %.	Reduction of Area %.
0·208	0·409	45·2	60·2	17	57·2
0·209	0·932	37·6	58·7	15	59·2
0·117	1·600	45·2	56·5	16	63·9
0·277	5·120	52·6	61·7	0	0·0

These results show that the elastic limit and tenacity are higher in the silicon steels than in carbon steels of the same carbon content; but these values do not sensibly increase with the content of silicon. Results obtained from the second series are as follows:

Carbon.	Silicon.	Elastic Limit.	Tenacity.	Elongation %.	Reduction of Area %.
0·878	0·433	62·5	115·2	5·5	10·4
0·838	1·156	62·5	103·9	4·5	10·4
0·968	2·090	76·8	105·4	3·0	0·0

These steels, again, have an elastic limit and tenacity superior to those of ordinary steels of the same carbon content. Further experiments on the mechanical properties of annealed and quenched steels are given, and of the latter the higher yield points and tenacities, compared with ordinary steels, are noteworthy. A further important feature is the high resistance offered to impact by quenched silicon steels, this property proving one of the most valuable of these steels.—**Léon Guillet,** *Rev. de Métall., Vol. I, No. 1,* pp. 46–67.—*P. L.*

PRIME MOVERS.

On Cylinder Condensation and Valve Leakage in Steam Engines.—I. (*Contd.*)

THE first of a series of articles in which the author gives an account of recent steam-engine research, as directed to the discovery of the causes influencing the magnitude of the difference between the total steam given to an engine and the amount of it which can be accounted for by the indicator. It is known that this "missing quantity" is from 20 to 50 per cent. of the steam actually supplied to the steam chest, and this difference is usually attributed to the action of the cylinder walls, which, by condensing the entering steam and re-evaporating it during exhaust, prevent this large percentage of steam from doing any work on the piston. The experiments of the author and Prof. H. L Callender, F.R.S., have, however, shown that the non-tightness of the steam distribution

valves is an equally important factor in accounting for this loss of steam—a factor which has been much under-estimated in the past. Hirn first investigated the nature and amount of the action of the cylinder walls, and as a result of the analysis of his experiments and of those of his pupils the following, among other generalisations, was enunciated: "The most economical working of a steam engine is attained when, by any method, the internal surfaces of the cylinder walls have been made perfectly dry before the beginning of release or when the expanding steam is dry at release." This proposition depends on the assumptions—(1) that any loss due to transference of heat from cylinder walls to steam, or *vice versâ*, during compression admission and expansion is small compared with the loss produced by re-evaporation from walls during exhaust; (2) that the transmission of heat from a dry cylinder wall into a current of exhausting steam is negligible in amount, whether that steam be dry or not. According to the author's experiments a considerable fall of temperature of the walls was observed after release, even where certain that the re-evaporation from the walls had been completed before the end of expansion, more than 40 per cent. of the whole heat alternately given up and received by the walls being rejected into the exhaust even under these ideal conditions. But all the heat thus received by the exhaust steam is not lost, as that part of the steam which has been longest in contact with the hot walls is retained in the cylinder at compression, and two-thirds of the heat received from the walls after release was present in the cushion steam in the author's experiments, tending to diminish initial condensation by heating the clearance surfaces and drying the admission steam. Should it appear that even with the best types of distribution valves made there is a sensible amount of leakage during expansion and compression, a serious modification of the method of constructing the diagrams of heat exchange will have to be made. The author proceeds to elucidate the laws of the flow of heat into and out of a metal wall whose surface temperature is continually rising and falling, by reason of its contact with a fluid of rapidly varying temperature. In considering the flow of heat through a metal surface the quantity of heat flowing through unit area in unit time is given by the equation $Q = k\frac{(t_1 - t_2)}{x} = ki$, where i is the gradient of temperature, or the temperature difference, between the two sides of the plate divided by the thickness of the plate.—**Prof. J. T. Nicholson, D.Sc., M.Inst.C.E.,** *Power, Vol. XXIII, No. 11.—A. H. G.*

New Forms of the Steam Turbine.

THE author commences by dealing in detail with a paper, recently read by Dr. Riedler in Berlin to the Technical Shipbuilding Society, on steam turbines. Dr. Riedler gives his reasons for anticipating that the steam turbine will replace the reciprocating steam engine to a large extent in the near future, but does not consider that the De Laval or the Parsons' turbines satisfy the requirements of the future. The objections to these two forms of turbine are fully considered in this paper, and the Rateau and Zoelly turbines are also briefly dealt with. Dr. Riedler then states the principles on which he and Prof. Stumpf worked to find a construction which should eliminate the disadvantages inherent in the Parsons' and De Laval types. "Reaction" working was definitely set aside because of the great wheel velocity required for efficiency. The conditions for utilising the "impulse" principle in a practically useful manner are then laid down, and some of the details of disc design and of dynamic action are considered.—**Robert H. Smith,** *Engineer* (Lond.), *Vol. XCVI, No. 25.—A. H. G.*

Corrosion of Steam Boilers.

THE author takes exception to the current practice of judging the suitability of boiler-feed water exclusively according to its hardness, *i.e.* its percentage in substances capable of forming scale. According to him the remaining components of the water should also be ascertained, as their presence also gives rise to noxious effects. In most cases the prevailing scale-forming substances are precipitated by means of soda and lime, sodium sulphate being dissolved and pumped into the boiler along with the water. After the water has been vaporised, the sodium sulphate will remain undissolved in the boiler water. Now, as with continued treatment, the concentration of the sodium sulphate is increased up to rather high figures, this salt will finally exert corrosive effects on the boiler plates. The various nitrates and chlorides, always present in boiler water, will, especially in the presence of air, be even much more noxious. Of these substances, magnesium chloride seems to be the most noxious, barium and sodium chlorides coming next. In order to obviate the destructive effects of such substances as do not cause incrustation, the author suggests maintaining their concentration below the limit at which they attain the property of attacking iron. The author states that soft water, containing a material percentage of salt remaining in solution, is more dangerous in this respect than a water otherwise equivalent, but containing a higher percentage of scale-forming matter.—**L. Vogt,** *Mittheil. aus d. Praxis des Dampfkessel etc., Betriebes; Stahl u. Eisen, Vol. XXIII, No. 23,* pp. 1361 1362.—*A. G.*

Gas Power for Central Stations.

CAREFULLY gleaned testimony proves that gas-power machinery is simpler, and can operate with higher economy at central stations than steam, and that a gas-works can profitably install a gas-power generating station, and supply both gas and electricity at competitive rates. The basis of this paper consists of data collected from some of the principal electric light and power plants in the United States, and shows that the cost of installation plants using natural gas is cheaper than steam, and the comparison of plants using producer and water gas to be parity. For economy and reliability, the evidence collected from nearly 500 plants is entirely in favour of gas power. The

average power capacity of 15 selected plants using natural gas is 400 b.h.p., of which the efficiency is 80 per cent. with belt-transmission and 85 per cent. when directly connected, the average consumption of gas per kilowatt-hour being 39 cub. ft. Gas plants have the advantage of not being hampered by steam-pumps, condensers, traps; nor by cylinder leakage and condensation, and have no heat losses when shut down. Many cases cited show that engines can be started while cold, and put on full load in from two to three minutes. There are several distinct fuel-gases available, of which a table is here given, showing the comparative values of the explosive mixtures from the various gases enumerated :—

Approximate B.T.U. Value per Cubic Foot.

	Gas.	Mixture.
Natural gas	1,000	91
Coal gas	650	92
Water gas	300	88
Carburetted water gas ...	600	92
Producer gas	130	64
Coke-oven gas	500	90
Blast-furnace gas	100	55

With the exception of furnace gas, the use of a different gas does not materially effect the cylinder proportions of an engine. Water gas is generally considered unsuitable for large engines with high compression, owing to its detonating action in the cylinder. To obviate this it is proposed to use additional holders and store the gases resulting from the blowing-up process, and supply this gas with the decomposed steam to the engine, either separately or mixed, thus reducing the percentage of hydrogen by the addition of a large volume of gas having a high percentage of carbonic-oxide, thereby greatly increasing the efficiency of the water-gas producer in making a double use of the gases that usually go to waste. A comparison of the thermal efficiencies of the various processes of making gas give 0·60 for coal gas, 0·70 to 0·85 for water gas, and 0·80 to 0·85 for producer gas. Therefore, with good coal the heat available at the engine with a good producer is 11,500 thermal units per lb., and is equivalent to a little more than 1 b.h.p. The extreme practical limit of steam engine economy is 10 lbs. of water per i.h.p. or 11 lbs. per b.h.p., which, with an evaporation of 10 lbs. per 1 lb. of coal does not give so high an economy as can be easily obtained in a comparatively small gas-power plant.—*Paper by* **J. R. Bibbins,** *presented before the Amer. Inst. E. E., rept. Eng. Rec., Vol. XLIX, No. 1.—E. B.*

The Design of Steam Turbine Discs.

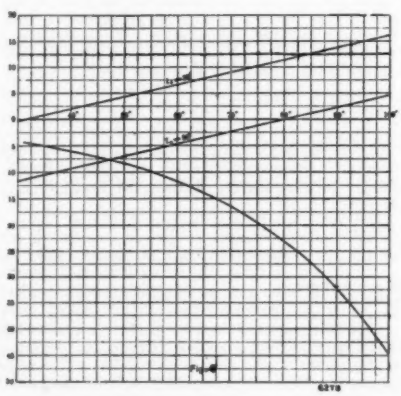
THE author investigates mathematically the stresses acting on a turbine disc rotating at high speed and neglecting the effect of tangential stress. Equations to the curves which form the bounding lines of the disc section are then deduced, both for a solid disc and for a disc with a hole in the centre. The equation for a hollow disc can only be deduced down to a certain critical point. Below this point general considerations determine the necessary breadth of the wheel.—**Frank Foster, B.Sc.,** *The Engineer, Vol. XCVII, No. 2506. —A. H. G.*

Theory of the Cooling Tower.

THE author assumes that the current of air in a cooler remains in contact with the water until it is at the same temperature as the water. Then if q = heat taken up by air, t_a = initial temperature of air, c_p = specific heat of air at constant pressure (= 0·24), we have, if t is the initial temperature of water on entering cooler: $q = c_p (t - t_a)$ B.T.U. per lb. of air Plotting this equation, we get for any value of t_a a straight line, cutting the t axis in t_a and cutting the q axis in $- c_p t_a$. The greatest heat loss from the water, however, is due to evaporation, and as each cubic foot of air will take up one cubic foot of water-vapour at a pressure corresponding to its temperature, we see that since $p v = R T$, or $v = \frac{R T}{p}$ where v = volume in cubic feet of 1 lb. of air at the pressure p (lbs. per square foot), where T is the absolute temperature of the air and $R = 53{\cdot}22$, we have, if w is weight of one cubic foot of water-vapour at temperature t, $w v = w \frac{R T}{p}$. Now amount of heat to evaporate one lb. of water at temperature $t^\circ = 1091{\cdot}7 - {\cdot}695 (t - 32)$ B.T.U. ∴ Heat taken up per lb. of air by evaporation is

$$Q = w \frac{R T}{p} \left\{ 1091{\cdot}7 - {\cdot}695 (t - 32) \right\}$$

In this equation $p = (1 - p_v)\ 14{\cdot}7 \times 144$ lbs. per square foot, p_v being the vapour tension at temperature t. The total heat taken up per lb. of air is therefore $Q + q$. Plotting both equations on one figure we get Fig. 1. If $t_a = 80^\circ$ and $t = 90^\circ$ we see that $Q + q = 34{\cdot}4$ B.T.U. The point of intersection of the two curves gives the minimum temperature to which the water may be cooled. —**H. L. Nachman,** *Power, Vol. XXIII, No. 12.—A. H. G.*



COOLING TOWER.

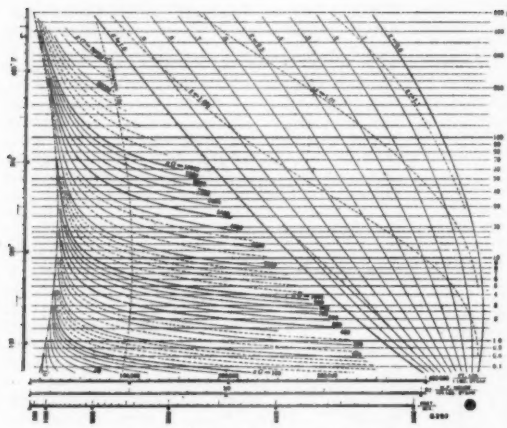


FIG. 1.—ADIABATIC EXPANSION OF STEAM.

Diagram for Adiabatic Expansion of Steam.

A GRAPHICAL method of determining the velocity of steam expanding adiabatically, the power developed, etc. The diagram (Fig. 1) is limited to saturated steam-pressures in lbs. per sq. in. absolute. As examples of the use of the diagram—(1) Steam at 100 lbs., containing 20 per cent. of moisture, expands adiabatically. In the diagram (Fig. 2) find the point A, corresponding to 100 lbs. pressure, and $x = 0{\cdot}8$, x being the dryness fraction. Join AP. Where AP cuts any line of pressures, say 5 lbs., as at E, the corresponding value of $x = 0{\cdot}71$ gives the dryness at that point. (2) To find the work done by 1 lb. of steam in expanding adiabatically as above from 100 lbs. to 5 lbs. pressure, from the point B, where the 100-lbs. pressure line intersects the dotted line $B\,D^1\,D$, draw BC parallel to AE. Then the length DC, measured on the upper scale, gives work done in ft.-lbs. The length DC, measured on the middle scale, gives h.p.-hrs. per 100 lbs. of steam. (3) A pipe delivers steam to a nozzle at 100 lbs. pressure and containing 20 per cent. moisture. To determine the area of nozzle corresponding to various pressures when 1,000 lbs. of steam per hr. pass through the nozzle. The curves marked $x\,G$ on the diagram give the weight of dry steam passing through each sq. in. of section of the nozzle per hr. The point C falls on the $x\,G$ curve giving 1,000 lbs. of steam per hr., and, as $x = 0{\cdot}71$, we have

$$G = \frac{x\,G}{x} = \frac{1{,}000}{{\cdot}71} =$$

1,410 lbs. per hour.

Therefore for 1,000 lbs. per hr. the area must be $\frac{1{,}000}{1{,}410} = 0{\cdot}71$ sq. in., and so on for different pressures. (4) To find the velocity with which steam would leave a nozzle when expanded from 100 lbs. to 17 lbs. pressure, the nozzle being formed as before. The line $E\,C\,D$ in Fig. 1 corresponds to 17 lbs. pressure; then the length CD, measured on the bottom scale, gives the velocity of the issuing steam, about 2,300 ft. per sec. With the given nozzle the velocity will not be altered by lowering the terminal pressure below 17 lbs. (5) In a steam turbine the steam enters one set of blades with a velocity of 1,500 ft. per sec., being dry and saturated, and at 70 lbs. pressure. The pressure is reduced adiabetically in passing through the blades to 50 lbs. pressure. To find the velocity of the steam on leaving these blades, from the point K, corresponding to 70 lbs. pressure, and $x = 1$, draw KP. Make $IL = 1{,}500$ ft. per sec. on lowest scale; draw LN parallel to KP; then the length of MN on the 50-lbs. pressure line gives the velocity to be 1,900 ft. per sec.—**Sven S. Ekman,** *Power, Vol. XXIII, No. 12.—A. H. G.*

NAVAL ARCHITECTURE.

Notes on Side Launchings.

THE method of constructing launching ways in instances where it is necessary to launch vessels broadside on is described, the systems chosen for descriptive purposes being those adopted in launching the cruiser *Galveston* and suction-

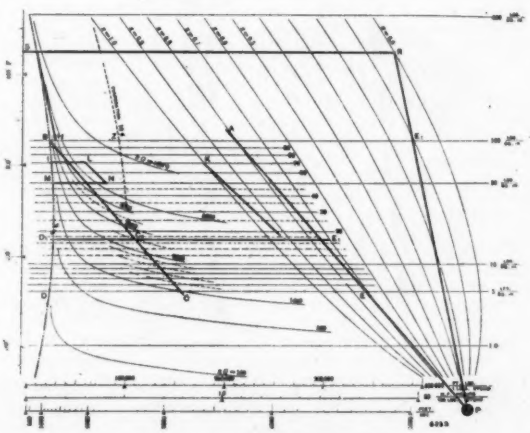
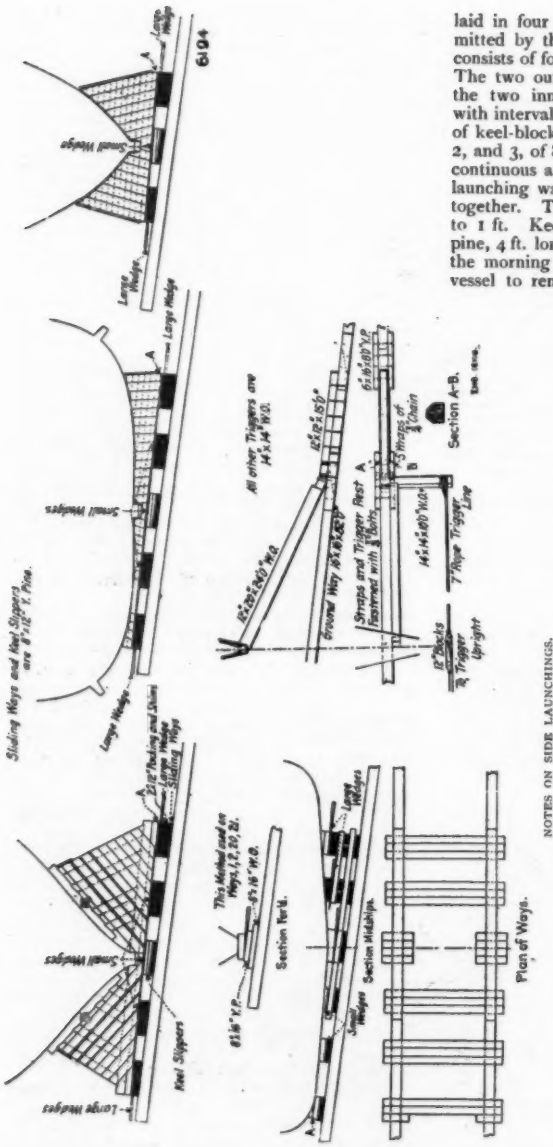


FIG. 2.—ADIABATIC EXPANSION OF STEAM.



dredge *Benyuard*. Figs. 1, 2, and 3 show details of cradles. There are 23 groundways of 16-in. by 16-in. yellow pine, the inclination being 1½ in. to 1 ft. The sliding ways are laid in four groups fore and aft, so far as is permitted by the shape of the vessel. Each group consists of four rows of 8-in. by 12-in. yellow pine. The two outer groups are continuous. Each of the two inner groups covers two sliding ways, with intervals between to facilitate the cutting out of keel-blocks. Tie-pieces, marked *A* in Figs. 1, 2, and 3, of 8-in. and 16-in. white oak are put in continuous across the ship on the eighteen middle launching ways, to tie the groups of sliding ways together. They are given an inclination of ¾ in. to 1 ft. Keel-sleepers of 8-in. by 12-in. yellow pine, 4 ft. long, in four rows, were not fitted until the morning of the launch, in order to allow the vessel to remain on the keel-blocks as long as possible. Six triggers of the ordinary dogshore type were used, details of which are given on Fig. 4. Procedure at launch, the vessel being on keel-blocks, keel-sleepers out, two lines of shores on either side of vessel: (1) Set up triggers, getting ropes as tight as possible; (2) remove distance pieces; (3) wedged home on outboard side of cradles, moderately inboard; (4) cut out keel-blocks in way of installation of keel-slippers; (5) put in keel-slippers and wedged up same; (6) wedged home in board cradles; (7) cut away shores, outboard first and then inboard; (8) cut out keel-blocks masked by inboard ways; (9) cut out keel-blocks not masked; (10) cut trigger ropes simultaneously and launched. The system adopted, as above, in the *Galveston* was much more elaborate than is generally the case, owing to the round bilges; and, owing to the vessel being sheathed, it was necessary to build up the cradles solid to prevent damage. The *Benyuard*, on the other hand, being a flat-bottomed ship, was packed up with any size material that came to hand, and the wedges located as was most convenient. In this vessel there were 21 groundways, spaced about 12-ft. centres, having an inclination of 1½ in. to 1 ft. The sliding ways were of 8-in. by 12-in. yellow pine, in five groups, as shown on Fig. 5. The way marked *A* is merely a trailer, and was put in to keep the bilge of the ship from dropping until well clear of the groundways. The sliding ways in general covered two sets of groundways, both on inboard and outboard sides. Keel-slippers were fitted on each groundway, those used on the *Galveston* being used in this case also. Large wedges used in the *Galveston's* launch principally

used in the *Benyuard's*. They were placed in position, as shown in the plan, under cribs and keel-slippers, and wedged up as they were put in, no distance pieces being used under sliding ways. Small wedges were used on the inboard side where there was not room to ram up the large ones. The arrangement of triggers, etc., on the *Benyuard* were similar in principle to those used on the *Galveston*. The order of procedure on the *Benyuard* launch was as follows: (1) Set up trigger ropes, getting ropes as tight as possible; (2) rally up wedges where possible; (3) cut out bilge shores; (4) cut out keel-blocks; (5) cut trigger lines and launch. Launching particulars:—

	Galveston.	*Benyuard.*
Groundways, yellow pine	16″ × 16″	16″ × 16″
Ground-shoes	none	none
Sliding ways	8″ × 12″	8″ × 12″
Inclination of sliding ways	1½″ per ft.	1½″ per ft.
Number of groundways ...	23	21
,, triggers ...	6	6
Bearing surface	494·76 sq. ft.	444 sq. ft.
Launching weight ...	3·21 tons	2·59 tons
Drafts after launching, fore	7′ 5½″	4′ 6″
,, ,, aft	10′ 11″	6′ 1″
Angle o keel at launch, est.	30°	10°
Length of vessel	292′ 0″	260′ 0″
Beam	44′ 5½″	47′ 6″
Accidents	none	(*a*) and (*b*)*

— Wm. G. Groesbech, M.Soc.N.A. & M.E., *Eng. News, Vol. L, No. 23*, pp. 497–499.—*H. B. D.*

MARINE ENGINEERING.

Screw Propulsion for Warships.

An interesting report is given in *Engineering* of a paper on "Screw Propulsion for Warships," which was recently read by Mr. Geo. Quick before the United Service Inst. Mr. Quick is well known as having been connected with some of the earliest experiments made with screw propellers in the Royal Navy. The author's opinion regarding the question is that a great deal might be said if information were more complete. This is clearly demonstrated by the events in regard to cruisers of the *Drake* class. With the original propellers these vessels gave a speed of just over 23 knots; this not being considered satisfactory, new screws were fitted, resulting in a speed of 24·11 knots on practically the same i.h.p. If the original screws had been retained, this speed would have necessitated 41,000 i.h.p., involving engines and boilers of 30 per cent. greater power than at present in the ship. If so much was done, it may be reasonably asked, could not more have been effected? In the author's opinion this is possible; he thinks that another knot could still be attained by further alteration in the propellers. Opinion is largely based on tank experiments, which may, without doubt, differ considerably from ordinary conditions, such as head winds and rough weather. After the limiting speed has been reached the ship resistance, and, consequently, the power required to overcome this resistance, rises rapidly. The author ascribes a large proportion of the excessive power needed to increased waste of power by the propeller at the higher speeds, and not to the increased hull resistance after the limiting speed is reached. Mr. James Hamilton, in his paper of 1898, read before the Institute of Naval Architects, on "Horse-power absorbed by Skin and Wave making," stated that: "There is good reason for believing that the percentages of total i.h.p. representing propeller waste and load friction are less in high than in low-powered vessels." That, Mr. Quick says, is quite true when the i.h.p. per sq. ft. of helicoidal surface of screw does not exceed a certain limit. The question of the ratio of helicoidal area of screw to horse-power is dealt with at some length. The contention was that, generally, decline in efficiency at higher speeds was due to an enormous waste of power owing to insufficient helicoidal area of blades, and to insufficient width at the ends of the blades, as well as to the radial form of the blades being unsuitable to the high speed of the propellers. It is suggested that in no case should there be more than 130 i.h.p. per sq. ft. of helicoidal surface in ships of 0·5 coefficiency of fineness, and in ships of 0·6 coefficiency of fineness the ratio of i.h.p. to helicoidal surface should be about 7 to 1. Details are given of trials, made in 1861 and 1862, with *H.M.S. Bullfinch*, in which a three-bladed propeller was substituted for one having two blades of practically the same diameter, pitch, and length. The three-bladed propeller had 50 per cent. more surface, and gave a higher coefficient of performance. Trials made with the *Shannon*, about the same time, are also given. In these it was found that a four-bladed screw gave higher efficiencies than others having two, three, or six. The author has come to the conclusion that it is possible to greatly increase the average speed of nearly all our high-powered steamships by increasing the helicoidal area by 30 or 40 per cent., and by the substitution of four-bladed propellers for three-bladed ones. It was shown in some experiments mentioned that the proportion of power spent in overcoming rotational resistances of screws rises rapidly with increased revolutions. By judiciously modifying the forms of the blades, the useless expenditure of power in churning could easily be avoided. The proposals to effect this are to increase the width of the blades at the ends, and by substituting four-bladed screws having 33 per cent. more helicoidal area. The advantages of triple screws are favourably discussed, the opinion expressed being that the centre propeller should only have two blades, in order that when not in use it might be placed vertically, and kept connected with the main engines ready for any emergency. The paper was concluded with a reference to the application of the hydraulic principle in warships. The author's opinion was that the warship of the future should have a portion of its power assigned to one or more steam turbines driving high-speed centrifugal pumps, which could be used for propulsion at low

*(*a*) Vessel hung for 17 mins. (*b*) Parted one stern check-line, due to chafe; other check-line pulled up check-post; vessel touched slightly on other side of basin.

speeds, or in assisting propulsion at the maximum speed. Another advantage of such an arrangement would be that it might be the means of keeping vessels afloat after injury from torpedoes, gun-fire, etc. The fleet having the largest number of cripples afloat after action, steaming at, say, only 8 knots, would be able to compel the surrender or complete the annihilation of the enemy. **—Geo. Quick,** *Engineering, Vol. LXXVI, No. 1,978,* pp. 738–39. Report of paper read before the United Service Inst.—*H. B. D.*

Note on the Direction of Rotation of Propellers on Twin-Screw War Vessels.

THE question as to which direction it is advisable to make twin screws turn has been in debate ever since the beginning of the use of twin screws. The reason which in late years has caused the adoption of both screws turning inwards on several vessels, is that—quite wrongly in the opinion of the author—it is the engine builders who decide upon the screws. The propeller is intimately bound up with the hull of the ship which it drives, and ought to be studied by the builder of the hulls. As to the engine builder, it suffices to give him an outline of a propeller which permits the absorption of the estimated power at a given number of revolutions. The adoption of screws turning inboard has, in the eyes of the engine builder, a very se uctive advantage—it enables the crosshead guides to be placed out-board, and consequently, in plain sight of the attendant. This is the only advantage. We think it must yield precedence to the advantages of screws turning out-board, which are of two kinds. In a single-screw ship, with the blades turning clockwise as viewed from the stern, the pressure on the lower blade when vertical—owing to the fact that it works in a more resisting medium—is greater than that on the upper blade. This results in the vessel falling to port. With two screws with blades turning out-board—if, in order to turn more rapidly, we stop the port one—the starboard screws tends to cause a falling-off to port. In the case of screws turning in-board, on the contrary, if we stop the port engine, the starboard screw tends to cause a falling-off to port ; but that effect is opposed to the action of the screw itself, which would tend to make the vessel fall off to starboard. From the manœuvring point of view there is, therefore, no doubt that the propellers ought to turn out-board—which diminishes the radius of the vessel's turning circles. The advantages in efficiency are next discussed at considerable length. The paper is concluded with a comparison of warships having screws both turning in-board and both turning out-board respectively. A remarkable instance of the difference which may accrue from the adoption of out-board turning screws over in-board turning screws is given, which amounts to 1·5 knots, namely, 27·25 knots for the first-mentioned principle, and 25·75 for the latter. The vessels compared were almost identical as regards i.h.p., displacement, immersed midship section, screws and immersion, etc.—**M. Laubeuf,** *Chief Constructor, French Navy (translation). Journal of Amer. Society of Naval Engineers, Vol. XV, No. 4, Nov. 1903,* pp. 1175-1184.—*H. B. D.*

Starting Large Gas-Engines.

THE paper is descriptive of the various systems adapted for starting marine gas-engines. The manipulation of large engines requires greater effort than can be imparted by a man to turn them over with sufficient rapidity for them to take up the cycle. Quite a number of different schemes have been used in the past in order to make it easy to start large engines. In a very large engine, where the horse-power runs up into hundreds, a small engine is connected with the large one to give it the starting effort through a system of gears. This engine can be readily started by hand, and when it gets up to speed it is thrown in connection with the large engine by means of a clutch, and the small engine is used to start the

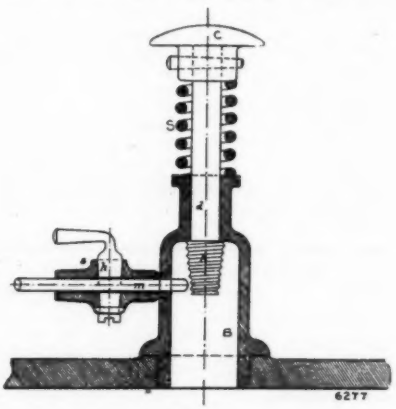


FIG. 1

STARTING LARGE GAS ENGINES.

large one. A still later development in starting mechanism is to charge the cylinder with a mixture of gasoline and air, to turn the engine over by means of a lever until the piston is just past dead centre, and then to ignite the mixture by means of a detonating mechanism. A good example of a detonating device is shown by Fig. 1. This starter consists of a steel body *B*, which screws into the compression space of the engine. In the top of the engine is the plunger against *d*, with corrugated taper head *A*, and at the outer end of the shank the cap *C*. The spring *S* keeps the plunger against the neck of the body on the inside, to which it is ground to form a tight joint. When about to start the engine, an ordinary match is inserted through the cock, and the plug *h* turned on so as to grip it. About a teaspoonful or more of gasoline is put into a priming cup and a charge drawn in with the engine at the expansion stroke, and all the valves closed, air to fill the cylinder

being drawn in through the priming cup. When the stroke is nearly or quite completed, the engine is reversed swiftly and turned as far as the compression and the strength of the operator will allow. Just as the piston begins to stop, a blow of the hand on the cap *C* causes the plunger *A* to light the match and fire the charge. The resulting impulse is usually sufficient to carry the engine through three or four revolutions, which will allow it to take up its cycle. After the engine is started the plug *h* is turned on, and the explosion blows out the match. The use of a match is not as a rule necessary with an electric igniter, and it is a very simple matter to arrange the hammer to break so that the spark can be produced by a blow of the hand; and, with a jump-spark system, a push button may be connected in a primary circuit of the coil, so that by pressing a button the circuit will be closed and a spark produced at the plug. Quite a number of marine engines have been fitted with a small air pump, operated by a worm and screw from the propeller shaft, and an air pressure between 60 and 100 lbs. is raised in the reservoir. This tank is connected, through a quick-opening valve, to the compression space of the cylinders. The engine is started by turning it over until one of the pistons has just passed the top of the stroke, when the valve is opened sharply and the pressure of the air starts the engine. The flywheel or crank-shaft must be closely watched and the air shut off before the stroke is quite completed, so that it will not retard the piston on the return stroke. Usually, one impulse is sufficient to start almost any engine; and as the impulse is in proportion to the piston area, the system works out very nicely, irrespective of the size of the engine, so long as the air tank is of sufficient capacity. The writer believes that the capacity of the air tank should be at least ten times the piston displacement of the engine. The general tendency among manufacturers is towards the use of the igniter for starting. In a few of the very large marine engines a charging pump for filling one or more of the cylinders with a mixture of gasoline and air is used to supplement the igniter. In starting an engine by means of a charging pump, the pump is arranged to draw air through the vaporiser, or else it is charged with a certain amount of liquid gasoline and air, and the gasoline vapour pumped into the cylinder with the crank-pin in that cylinder just past the upper dead centre. As soon as the pressure is sufficient to start the flywheel the charge is ignited, and the ensuing explosion gets the engine under way.—**E. W. Roberts, M.E.,** *Marine Engg., Dec. 1903, Vol. VIII, No. 12,* pp. 601-602.—*H. B. D.*

Internal-Combustion Motors for Canal-Boat Traction.

THERE seems to be promise of a wide field of usefulness for the internal-combustion motor in the propulsion of canal boats. Of first importance in this respect is the economy which the new types of motor offer in comparison with that of the steam engine, and which in this respect seems to give the combustion motor an important point of relative advantage. More than twenty years ago there existed a commercial demand for some type of steam canal boat. It was found that the weight of the engines and boilers, under the then existing conditions, seriously reduced the available capacity for cargo, and also that the waves caused on the speeds attempted did much damage to the banks of the canals. An attempt was made to transfer the motive power to the land, and thus there were introduced at an early date steam locomotives, which towed the boats by a suitable arrangement of cables. The first efforts to adopt electric power took the form of electric trolley lines along the banks of the canal. The results of the development of this system were far from satisfactory. As the principal objection, it was recognised that the boat remained constantly dependent on a central source of power, and that every disturbance in the supply of power exercised a serious influence on the cost of operation. Eventually attention became concentrated on the internal-combustion motor. As this type seems adequate for all demands, as it requires no specially equipped engineer for its care, as it takes but little from the carrying capacity of the boat, so must the cost of operation through the installation of such type of motors become materially reduced. Attention must be paid to the protection of the canal bed and banks from injury by washing. These latter conditions the Deutzer Gas-Motor Company have met by the use of a propeller carried on a shaft, which may be elevated or depressed according as the conditions may demand. The chief purpose of the adjustable screw-shaft is to provide for a continuously uniform immersion of the propeller, whether the boat is deep or only lightly laden. Particulars and sketches of the arrangement are given of a boat having three shafts. The motor has 16 h.p., and can attain a speed of a little over 2 mls. per hr. with 270 tons load. In order to bring about greater simplification a later boat was fitted with but one central adjustable propeller. This adjustable propeller operates as well under light conditions as under full load. In this case, furthermore, the propeller was of three blades, in order that the blades might be made reversible for backing and going ahead without reversing the motor. The second point of importance relates to the practicability of a producer-gas installation. The methods which have been mostly in use during the past fifteen years for the generation of producer gas have involved the passage of a blast of steam or air through glowing coals. With such an equipment a steam boiler and holder for gas was requisite. Through a great simplification in the methods of operation, however, the possibilities of this gas have recently received a new significance. Both boiler and gas-holder may be dispensed with, and the action of the piston within the cylinder on the entering stroke is found sufficient to form the vacuum in the pipes leading to the cylinder necessary to draw through glowing coal a charge of air laden with vapour, which thus automatically enters and fills the cylinders. The generator, which consists of a small roasting oven, contains in its upper part a water shell, which is heated by the action of the gases themselves. The entering air thus becomes saturated with water vapour over

the surface of this water, and is thus brought into the condition necessary for the formation of gas; then, by passage through a layer of glowing coal, the gas becomes charged with carbon monoxide. Before admission to the motor the gas is cooled and cleaned by passage through a water spray. The gas after being generated is collected in a holder in the top, thus providing a reserve supply and a more uniform flow to the engine. In starting up the apparatus the necessary air blast must naturally be supplied by a hand-blowing device. During this period the smoke and gases are led away through a funnel provided for the purpose. The special advantage of the producer-gas installation for river and canal-boats consists primarily in the decrease of the cost of operation, as compared with combustion-motors using benzine, petroleum, or wood alcohol. In Holland the two latter can be obtained in any quantity, since there are no imposts; but in Germany and France the expense would be prohibitive. For example, if we take a river steamer of, say, 275 tons, and with a speed of about 2 mls. per hr., requiring about 7 h.p. to 8 h.p. per mile-hr., then in Germany or France the cost of propulsion with spirit or gasoline would be from 16 to 20 cents per mile-hr. With producer gas, in an installation similar to those above described, these figures would fall to from 2·5 to 3·7 cents.—**Julius Kuster,** *Marine Engg., Jan. 1904, Vol. IX, No. 1,* pp. 17–20 (translation).—*H. B. D.*

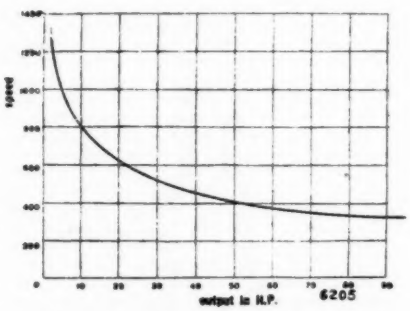
ELECTRICAL ENGINEERING.

Pulsations of Current in Converters.

The author investigates the so-called Banti phenomenon, consisting of current pulsations as occurring in converters. In a former paper he had shown by experiment these pulsations to increase on one hand for increasing intensities of the alternating current, and on the other hand for growing phase differences between the above current and the e.m.f., the latter increase being the more rapid. In this paper the hypothesis is confirmed that a variation of these pulsations should be produced by altering the magnetic saturation of the inductor cores, in addition to such variations as are due to alterations in the current and phase difference. In order next to explain more fully the phenomenon of current pulsations being due to an oscillation of the differential e.m.f. of the circuit, the author used a distribution circuit with non inductive loads, inserting a regulating resistance in the circuit of the armature, variable from 1 to 8 ohms, when the attenuating influence of the resistance on the phenomenon in question was shown to be the greater as the resistance was higher. This accounts for the fact that the readings of voltmeters show no appreciable differences from one another, as the current traversing them is directly proportional to the principal tension, the absolute value of which does not undergo oscillations. From experiments with inductive loads in the utilisation circuit, it is inferred that the phenomenon of current pulsations in the circuit of converting machines is, in the first place, due to variations in the inductive flux, as produced by the reaction of the armature. With equal values of the current intensity in the armature, these reactions will in fact be the more marked as the iron is farther from saturation, and as the alternative force shows a greater difference of phase with respect to the e.m.f.—**Carlo Montu,** *Elettricita 22, No. 52, Dec. 27, 1903,* pp. 822–824.—*A. G.*

Speed Variation of Continuous-Current Motors by Shunt Control.

It is generally supposed that this method of speed control, although efficient, has a very limited range and application, because it necessitates the installation of much larger motors than would otherwise be necessary; but, in reality, it is of all known devices the one most adapted to satisfactory speed variation over the widest range. Were it not for commutation considerations, a motor would be chosen just as large and no larger than is necessary for giving the



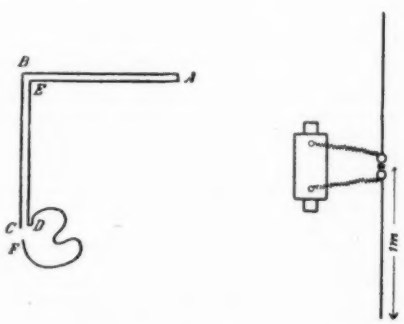
VARIATION OF CONTINUOUS-CURRENT MOTORS.

desired output at the lowest speed at which continuous operation is required, but a variable-speed machine must be designed for good commutation at the highest speed which it will have to attain. However, for moderate maximum speeds this design may still be also the cheapest design, and no rating down will be necessary on account of its being a variable-speed or reversible motor; but its cost must, of course, be compared with a constant-speed motor giving the same output at the same continuous running speed. The accompanying curve shows, for 250-volt moters, the maximum speeds relatively to h. p. which will permit of sparkless operation with the brushes in the geometrically neutral position, and with a design which, as regards diameter and length of armature, is proportioned for minimum cost. The curve for 500-volt motors would lie below, and that for 125-volt motors above the one given. The standard speeds now in use are considerably above those in the curve, and have probably been adopted in the belief that the higher the speed, the lighter and cheaper the motor; but this only holds good to a very limited extent with con-

tinuous-current motors, because the lower the speed the more favourable to low cost may the ratio of armature length to diameter be made. A moderate reduction of the present speeds would render possible the production of wide-range variable-speed shunt motors without extra cost or special design, but liberal provision would have to be made for ventilating the armature core and the highest practicable sub-division of the commutator. The author considers that the time has come for standardising the practice of operating motors at all loads with the brushes at the geometrically neutral point, instead of merely requiring "fixed brush position for all loads," as is now the usual practice.—**H. M. Hobart,** *Elec. Rev., Vol. LIII, No. 1,385,* pp. 926–928.—*E. J. W.*

The Multiplicator Rod, being a Wave-meter for Wireless Telegraphy.

THE problem is considered as to the means to be adopted of determining rapidly and safely the wave length of a sender. In the case of a direct measurement being made the instrument would have to fulfil the following conditions: (1) It should indicate the wave length as formed in the free space; (2) it



THE MULTIPLICATOR ROD.

should be susceptible of being standardised; (3) it should be easily transportable and of easy handling; and (4) it should ensure an accuracy of at least 1 per cent. The instrument designed by Prof. Slaby satisfies all these conditions, its accuracy being even higher than that corresponding to the above, in addition to the handling requiring no special skill. A linear vibrating system, as represented in Fig. 1, generates quarters of a wave length of 1 m., the vibrations being absorbed by a receiving loop bent at right angles, when the tensions in *C* and *D* will be perfectly identical and of the same phase, and the tension curves in *A B C* the same as in *A E D*. When connecting to *D* a wire *D F*, 2 m. in length, so as to allow of a half-way being formed, a phase difference as high as 180 degs. was obtained at equal tensions; the tension between *F* and *C* was, therefore, nearly twice the one formerly observed between *C* and *D*. When winding, however, this additional wire in the form of a coil, the author observed a material further increase in tension up to multiple values; this instrument was termed "tension multiplicator" by the author. Such multiplicators, the underlying principle of which have, by the way, been stated already by Teslar and Oudin, have, for two years past, been applied to wireless telegraphy systems. After a theoretical study of the phenomena occurring in the multiplicator rod, the author states a method of standardising instruments in terms of wave lengths, it being shown that the multiplicator rod affords an extremely simple and most available means of checking the tuning of wireless telegraph stations.—**Prof. A. Slaby,** *Elektrotechn. Zeitschr., No. 50,* pp. 1007–1012.—*A. G.*

A New Hysteresis Meter.

THIS instrument has been designed by M. Blondel for measuring the hysteresis coefficient of samples of iron at a single reading. It comprises no parts liable to get out of order, as it is intended for workshop use, and it gives results accurate to within 2 to 5 per cent. A **U**-shaped permanent magnet is mounted with its arms pointing vertically upwards and its yoke resting upon a pivot underneath, so that it can revolve about a central vertical axis. The sample under test is in the form of a ring, and rests horizontally between the poles of the magnet upon a supporting plate mounted on pivots, also in the same vertical axis, but it can only turn against the tension of a spiral spring. When the magnet is revolved by means of a friction drive from a shaft terminating in a small milled wheel, the flux through the test-ring continually changes its direction, and by reason of the hysteresis, which acts like a friction effect, the ring and its supporting plate are dragged round until checked by the opposing couple due to the spring. Experiment has shown that the hysteresis pull is practically independent of the speed of the revolution of the magnet, so it is constant per revolution, and proportional to the angle of displacement, which is indicated by a pointer attached to the axis of the supporting plate and read on the dial of the instrument. In practice the magnet is first revolved in one direction, and then in the other, for, by taking the double angle between the two readings, the results are more exact, and errors due to previous magnetisation of the iron are eliminated. The hysteresis co efficient is derived from the reading by comparing it with the angle of displacement due to a standard ring whose coefficient η is known; the values being in the same ratio as the respective deflections. The standard ring is constructed from a quality of iron not likely to change its coefficient, but it can easily be returned to the makers of the instrument for occasional recalibration. The test-rings are built up of a number of thinner rings, each of 55 mm. exterior and 38 mm. interior diameter, and all together about 4 mm. in thickness.—*Elec. Rev., N. Y., Vol. XLIII, No. 23,* pp 806–807.—*E. J. W.*

Eddy Currents in Dynamo Machinery.

If in any machine the field current shows a synchronous variation of about 10 per cent., due to armature reaction, the loss in the field core by eddy currents will be a large fraction of the total losses. Such losses have generally been thought to be confined to alternators, but there are four possible sources of disturbance even in continuous-current machines, viz.: (1) Imperfect centring of the armature or adjustment of the air-gaps. These effects are most prominent at light load. (2) Variation of reluctance caused by the teeth of the armature moving across the pole face. (3) Slight peripheral shift of the cross magnetising belt to and fro during commutation. (4) Variation of reaction set up by a rise and fall of armature current, due to phase swinging or uneven turning moment of the engine. The second cause is known to be operative by the heating of the pole-faces with slotted armatures, and by the aid of curves obtained with the oscillograph the author proves that the other three are equally active.—**W. M. Thornton, D.Sc.,** *Paper read before the I.E.E., Newcastle; Report Electrician, Vol. LII, No. 11,* pp. 419-422, *No. 12,* pp. 449-450.—*E. J. W.*

The City and South London Railway.

For the first nine years of its existence, the original line—3½ mls. long—was worked on the plain two-wire system at 500 volts; but since it has been extended to over 6 mls., a three-wire system—with the rail as middle wire, and accumulator sub-stations—has been introduced. 500-volt generators are connected between the rail and the "up" and "down" working conductors respectively, and between the latter and the feeders to the two sub-stations are other 500-volt generators; so that the whole forms a kind of five-wire system with 2,000 volts across its outers. The reducing motor generators at the sub-stations are mechanically coupled in pairs—the one on the "up" and the other on the "down" side—so that they also act as balancers. The generator part of each machine delivers current at 500 volts between the working conductor and the rail, when the motor part on full-load receives current at 430 volts between the high-tension feeder and the working conductor, thus providing compensation for a line drop of 70 volts. At the further sub-station a Highfield booster is installed in connection with the battery; while at the generating and other sub-station ordinary non-reversible boosters are employed. The result of these arrangements is to give an almost perfect voltage regulation throughout the line. About one-half of the total energy generated is delivered to the line without any transformation; that is to say, at 500 volts. The over-all distribution efficiency at the feeding points is as follows: Close to the generating station, 99·3 per cent; at 1·85 mls. away, 96·6 per cent.; at 2·77 mls. away, 86·0 per cent.; at 5·10 mls. away, 81·6 per cent.; the latter point is the extreme end of the line in one direction. The average efficiency over the whole system is 90·9 per cent., or 90 per cent. when allowance is made for the average loss in the working conductors between the end of the feeders and the locomotives. Full particulars are given of the prime movers and their performance; of the lighting and electric lifts, and arrangement of their circuits, and of the general working of the system under various conditions.—**Peter Valentine McMahon,** *Paper read before the I.E.E., London, Dec. 1903; Report Elec., Vol. LII, No. 9,* pp. 332-5.—*E. J. W.*

Electric Traction with Alternating-Currents.

For suburban, urban, and interurban tramways and railways the author considers three-phase working to be out of the question on account of the two conductors required, apart from considerations of uniformity of line and rolling-stock equipment; nor does it seem likely that single-phase systems will offer sufficient inducements for this class of work; but for the light railways and high-speed point-to-point lines the future probably lies with alternating-current systems by reason of their smaller first cost and lower operating expenses. Comparing typical 500-volt, 80-b.h.p. railway motors of approximate equal weights and dimensions of the direct-current and of the three-phase 25-cycle type shows that the latter has quite as good an efficiency at all loads. Its power-factor is somewhat lower than usual owing to the considerable air-gap necessary for traction work. The cost of the three-phase motor and its equipment is decidedly greater, chiefly because of the expensive nature of its controlling gear, but it has the advantage with respect to the up-keep and its suitability for the direct application of the high-pressure current, which however the author advises should not generally exceed 2,000 volts. The weakest feature of three-phase motors is their speed control, as it involves great waste and considerable complication, the difficulty increasing when rapid acceleration is required. Besides, they have no inherent regulating properties, but take all loads within their compass at nearly the same speed, the practical result being that the generating station and sub-stations may have to be of 30 per cent. greater capacity than for an equivalent continuous-current system. Another difficulty was the necessity for the maintenance of a fairly constant line pressure at the motor terminals, as its torque varies as the square of the pressure; but now that compound three-phase generators of the Heyland type are available this part of the problem is completely solved. Rheostatic control in the motor circuit is employed on all three-phase lines up to the present, except the Valtellina Railway, and there Messrs. Ganz & Co. have introduced tandem parallel control. In this arrangement approximately half sychronous speed is obtained by connecting the stator of one (the primary) of two mechanically-coupled motors direct to line; while the stator of the other (the secondary) is short-circuited on itself, and the two rotors are put in series. For intermediate speeds, resistances have to be introduced into the circuit of the secondary stator. The maximum torque of the two motors in tandem is somewhat less than of one running alone, and the

maximum output is only about one-fourth that of the two motors in parallel. The efficiencies and power factor are also considerably less when the motors are in tandem; but above half sychronous speed the stator of the primary motor returns power to line, and this has been found to amount to some 12 per cent. on the Valtellina line. Four motors of equal size are employed per car: two primary 3000-330 volts, and two secondary 330-330 volts. The two latter are only in use from standstill to half-speed when accelerating, and from full-speed to half-speed when braking; the rest of the time they are out of circuit and running idle. The feasibility of single-phase working will be determined entirely by the motors. There are three kinds applicable to traction purposes, namely, series motors, repulsion-induction motors, and repulsion-series motors. The characteristics and shortcomings of each of these types are described and discussed in some detail. The author believes the latter are the most promising, as their power factor is nearly ninety under all conditions.—**A. E. Eborall,** *Paper read before I.E.E., Dec. 1903; Report Electrician, Vol. LII, No. 9,* pp. 327-330; *No. 10,* pp. 371-5.—*E. J. W.*

Copper Losses and Utilisability of Double-Current Generators.

CONSIDERING the working of a machine, the design of which is analogous to that of a rotary convertor, F. Horschitz arrives at the following conclusions: Single-phase generators, provided the alternating-current load exceeds 25 per cent. of the maximum direct-current load, will show the highest losses and lowest utilisability as compared with any monophase double-current generators. The rotary-current direct-current generator as mostly used in practice shows a satisfactory utilisability as long as the apparent rotary-current output does not exceed 67 per cent. of the maximum possible direct-current output; *i.e.* as long as, for instance, an armature for 100 kilowatts of direct current has not to supply upwards of 67 kilowatts of rotary current (with $\cos \phi = 1$). It is advantageous to increase the number of phases on account of the diminution in the copper losses and the better utilisability of the armature as attendant thereupon. Increasing the number of phases beyond six, however, is not advisable, no material further decrease of the copper losses being observed in that case.—**F. Horschitz,** *Elektrotechn. Zeitschr. XXV, No. 2,* pp. 21-25.—*A. G.*

Hackethal Wires for High-Tension-Current Lines.

THE dangers inherent in high-tension lines (even when of quite satisfactory design) in the case of their being injured as soon as the insulation of the wire is ignited, through the supertensions attendant on short circuits, have been a serious objection to the general adoption of the best of artificial lighting methods. On the other hand, the first cost of the wire is somewhat increased by the safety regulations officially imposed in the various countries. The author therefore points out the minium insulation system invented by Mr. Hackethal, Hanover, which is little known to high-tension-current engineers, while in telephone and telegraph engineering this method is largely used. Linseed oil, to which minium is added, shows an extremely high insulating power, which increases with time. Wires insulated with this are remarkable also for their safety against fire, the insulation being only dried in the case of a very high load and sometimes carbonised, but never ignited. Such wires, 6 mm. in diameter, were charged for several hours at the rate of 50 amps. to 60 amps. per sq. mm. without any objectional phenomenon being noted. Hackethal wires 1·5 mm. in diameter were loaded up to 100 amps., when the impregnating mass of the cover was vaporised and the texture carbonised, while adhering to the wire. In the course of this experiment the intensity of the current increased up to 50 amps. on account of the increase in resistance.—**Bn. Böhm-Raffay,** *Elec. Techn., Vol. XXII, No. 17,* pp. 396, 397.—*A. G.*

LIGHTING, HEATING, AND VENTILATING.

Radiation and Illumination.

AFTER a short discussion of the Stefan-Boltzmann law and Wien's laws, the writer of this paper deals with the experiments which have been made on the temperatures of incandescent bodies, and gives a table of Lummer's values for the temperature limits in absolute degrees for the wave-length of maximum energy in the arc lamp, Nernst lamp, Welsbach lamp, electric incandescent lamp, candle, and Argand burner. The views of R. von Helmholtz upon radiant energy in gases are next noticed, and then the writer returns to actual estimates that have been made of the temperatures of the sun and stars. All these estimates are, of course, uncertain. The paper concludes with a discussion of the relationship between light and heat rays and how it is affected by temperature. It is shown that at a red glow an increase of temperature leads to an increase of light, measured by the 30th power; but when we reach a white heat, the increase of light due to increase of temperature is as the 14th power. The total radiation increases only as the 4th power of the temperature; and it is pointed out that the abnormal increase in the light yield is really due to physiological causes, as the eye is much more sensitive to the small waves produced at very high temperatures than to the coarser, colder waves. This suggests whether higher temperatures might not be used for ordinary lamps, and the closing remarks relate to our limitations in this respect. —*Engineering, Vol. LXXVI, Dec. 4, 1903,* pp. 751, 752.—*W. C. H.*

Osmium Lamps.

THE author endeavours to determine as accurately as possible the temperature of osmium lamp filaments (using a process designed by Prof. H. F. Weber at the 1891 Frankfurt Congress) from the relation given between the absorbed energy and temperature. He derives as an average value of the radiation constant the figure $C = 0{\cdot}0000164$. As an average of all the measurements made on osmium lamps,

1,435 degs. Cent. is found to represent the temperature of normal luminous intensity, being 135 degs. below the corresponding temperature for ordinary glow-lamp carbon filaments. The striking result that the normal temperature of the incandescent filament is so materially below the one of carbon filaments, though the economy of osmium lamps be much better than that of ordinary carbon filament lamps, is illustrative of the high luminous power of the osmium filament. In virtue of this behaviour the life of osmium lamps may evidently be much higher than the life of ordinary carbon lamps.—**Prof. L. Lombardi,** *Electrotechn. Zeitschr., Vol. XXV, No. 3,* pp. 41–43.—*A. G.*

TRACTION.

The Electrical Reconstruction of the South London Tramways on the Conduit System.

THE paper first gives a short sketch of the events which led up to the adoption of the conduit system of electric tramways for the central portion of London, and states the reason why a centre conduit was chosen in preference to a side conduit. The lines of which the reconstruction is described are those known as the "Tooting Lines," extending south of the River Thames from three northern termini at Westminster, Blackfriars, and Waterloo Bridges, to a southern terminus at Tooting. The route length of the lines in question is slightly over 8 mls., and the length of single line 16¾ mls. Dealing with the roadwork and permanent-way construction, the paper describes first the structure of the conduits, which are 2 ft. deep by 1 ft. 2½ ins. wide. This consists chiefly of cement concrete and cast-iron yokes, the latter spaced at 3-ft. 9-in. intervals, which support the slot-rails, and form a template to which the concrete panels are moulded. Chambers are formed at intervals of 5 yds. for the reception of the insulated supports from which the ⊢ shaped conductor-bars, supplying current to the cars, are hung. These insulators have a porcelain body, in appearance like an inverted jar, and are protected and secured in an iron cap, which is bolted to the slot-rails. The steel rod which carries the conductor bars is cemented to the inside of the porcelain cup, and the actual attachment to the bars is made by means of cast-iron clips capable of adjustment by means of an eccentric washer. The conductor bars have a sectional area of 2·15 sq. ins., and, under test, they have given $\frac{1}{7{\cdot}14}$ of the conductivity of Matthiessen's standard of pure copper. The separate insulated supports were subjected to a 2,000-volt alternating pressure in the shops, and after erection in place the whole electrical system was subjected to a similar test between conductor-bars, and 1,000-volt alternating pressure between conductor-bars and earth. The bars are placed symmetrically in the conduit 6 ins. apart, and the minimum air-gap between the conductors and conduit structure is 2 ins. Drainage of the conduit is provided for by connecting it to the sewers at intervals of 60 yds. These connections pass through a settling chamber, which intercepts the mud from passing into the sewers. The slot-rails are supported by the yokes, and the track-rails by an 8-in. concrete bed, and both are held to gauge by tie-bars fixed to projecting lugs on the yoke head. At junctions and crossings steel castings take the place of the rolled rails, and specially wide yokes are used to embrace the converging conduits, and to support the track rails as well as the slot rails. The mechanism for operating the slot and track points at junctions is contained in a concrete pit built immediately underneath the track. Both track points are fitted with 8-ft. movable tongues, which are connected together to the slot leaves by a series of cranks and adjustable links, so that the whole can be moved in unison by inserting and manipulating a lever either in a box in the footpath, or alongside the track. The free end of the slot leaves is bevelled off, so that a car trailing through can push over the points without any external assistance. A feature about the work is that at no part is the slot wider than ¾ in., and the arrangement for maintaining this at points and elsewhere is described. The paving material, except in the margins, which are laid to suit the existing material in the street breasts, is of granite setts, bedded on cement concrete, jointed with bitumen and cement mortar. The line is divided into half-mile electrical sections, each half-mile section being fed by separate distributors, connected to the sub-station switchboard bus-bars; the positive through a maximum cut-out and ammeter, and the negative through an ammeter only. By means of these appliances and a double-pole change-over switch, a perfect control of each section of the line is maintained. The current is generated by two 1,500-kilowatt continuous-current sets erected in a station at Loughborough, from which feeders convey current to the three sub-stations at the Elephant and Castle, Brixton, and Clapham, and are connected direct on to the bus-bars. The normal difference of pressure between conductors at the main station is 625 volts, and on the line approximately 550 volts. The method of dealing with faults on the line is described, and diagrams and drawings are given to show the method of connecting up the conductor-bars at junctions and crossings. The collection of current is effected by an arrangement called a "plough," which is suspended from horizontal transverse girders fixed to an extension of the side frames of one of the car-trucks. The actual contact is made by two cast-iron shoes, mounted on a wooden diaphragm at the bottom of the plough-shank, and pressure is maintained against the conductor-bar by the aid of flat steel springs. Flexible copper fuses, set to blow at 200 amps., connect the shoes to the copper leads, which are laid in chases, inside the plough-shank. From the lead top terminal cables are taken to the car-motors. The cross-girder of the carrier, from which the plough is hung, has open ends, and is so designed that in the event of a plough taking the wrong road at points, it can travel to the side of the car and drop off without causing any damage. In its normal position the plough can be released by withdrawing a bolt,

which frees a hinged flap, and allows the plough to slide down out of the guide. The last part of the paper is devoted to a description of the operations, and deals with the difficulties attending the work of reconstruction, and the methods of handling the work. The paper is accompanied by numerous illustrations, and by an Appendix giving the comparative cost of electric conduit construction as compared with cable conduit construction. —**A. Millar, A.M.Inst.C.E.,** *Proc. Inst. Civ. Eng., Jan. 1903.*

Electrification, Efficiency, and Economy.

THIS paper deals with the conduct of traffic upon the Manhattan Railway Division of the Interborough Rapid Transit Company of New York. Under the old steam conditions the maximum carrying capacity of the system had been reached, but the change to electricity has enabled no less than 17,384,556 more passengers to be carried during the last six months, the total being 125,548,740, as compared with 108,164,184 for the corresponding period to September 30th, 1902. The economy in operation is probably the most striking feature of the remarkable figures quoted. Under steam, the Elevated of New York was operated at 51·19 per cent. of the gross receipts which, judged by English standards, was a low ratio, being a point below that of our Metropolitan for 1902 and two points below the Metropolitan District. With electricity the Elevated's ratio has been brought down to 42 per cent., and it is almost certain to go lower for the year, as the heavier half has yet to come, and the experience of the six months has shown that the expenses are likely to be very nearly a fixed quantity, not varying very much with traffic fluctuations. Probably it will be as low as 37 per cent., which according to the chairman of the City and South London is the ratio for that line, exclusive of the lifts. The Central London cost 52 per cent. to work in 1902 with electric locomotives and including the lifts, but probably this will be reduced now that the multiple-unit system has been adopted.—*Railway News, Vol. LXXX, No. 2082, Nov. 28, 1903,* p. 775.—*C. S. L.*

Locomotive Counter-balancing.

THE first part of this paper defines the character of the several forces which produce disturbance, and it is shown that their magnitude and direction are the same whether the forces are calculated directly from the actual trochoidal path followed by the rotating parts, or from the circular path at its corresponding points. The crank-pin and all unsymmetrical portions of the wheels, together with the parallel connecting-rods, do not revolve about a fixed centre; but each particle of the rod and its attached parts moves in a circular path of the same radius as that of the crank-pin, and the same normal force is required to restrain it from leaving such path at a tangent. The resultant normal restraining force required for the entire rod is distributed between the crank-pins in the same way as the weight of the rod is divided between them. It is thus simply essential to determine the portion of the weight of the parallel rods carried by each crank-pin, and add it to the weight of the crank-pin and the unsymmetrical part of the wheel provided to support the crank-pin. The total weight thus found, multiplied by the crank radius, is equal to the product of the necessary weight of counterpoise, and the distance of its centre of gravity from the centre of the wheel. The difficulty in balancing the main connecting-rod of an engine arises from the fact that while one end moves in a circular path, the other end has but a simple reciprocating motion of translation; and, at intermediate points, the paths described by the various particles consist of different combinations of the two simple motions. As the length of the reciprocating movement at the centre of the crosshead-pin is the same as the diameter of the circular path of the centre of the crank-pin, it is obvious that every particle of the rod's mass has the same horizontal motion of translation, while the vertical movement varies. The author makes a complete mathematical analysis of the forces produced by the motion of the main rod and reciprocating parts, and gives a series of formulæ which offer a ready means for correctly balancing the locomotive.—**R. A. Parke,** *Trans. New Eng. Rlrd. Club, Rept. Rlrd. Gaz., Vol. XXXV, No. 50,* pp. 879–880.

Comparative Experiments with Saturated and Moderately Superheated Steam in Locomotives.

THE experiments described in this paper were made on behalf of the Breslau Royal Railway Department, two high-speed train locomotives being fitted with Pielock superheaters, and compared with two similar locomotives without superheaters as to their consumption of water and coal. The main results arrived at may be summarised as follows: (1) the temperature of the steam leaving the superheater being 260 degs., the saving as to water vaporised was about 16 per cent., and as to the consumption of coal, 12 per cent., whereas the steam saving proved equal to about 10 per cent. for a mean steam temperature of 230 degs. in the dome; (2) the consumption of steam in the different locomotives compared proved the same for equal outputs; (3) the weights of water vaporised are inversely as the specific volumes of the various kinds of steam, being directly proportional to the specific weight. The saving in steam obtained corresponded with the increase in the specific volume of the steam due to superheating; (4) the saving in steam, being dependent only on the superheat, must be the same both in compound and twin locomotives for equal superheat; (5) slide valves could be used up to the highest temperatures attained (272 degs. Cent.), provided sufficient oil was supplied to the sliding surfaces by means of lubricating presses; (6) in order to fully utilise the advantage inherent in superheating, the cylinders should be increased proportionally to the greater coal consumption of the locomotive without superheaters, as against locomotives with superheaters.—**Strahl,** *Zeitsch. des Ver. Deutsch. Ing., Vol. XLVIII, No. 1,* pp. 24–31.—*A. G.*

MECHANICAL.

Fly-Wheels on Machine Tools.

In some cases the driving-belt and driving-pulley serve to store energy; in others the addition of a separate balance-wheel is necessary. To determine when the energy of the running belt is sufficient, or when the addition of a separate wheel is advisable, all operating conditions of the machine must be known. In modern slotting machines the balance of power is obtained by the use of a heavy driving-pulley and heavier belting than was at one time the practice, and a larger ratio of driving gears is now used. In planing machines the quick reversals of the gearing and of the platen render necessary the application of considerable power for short periods. The increased power so required is sometimes greater than that required for taking the cut, or moving the platen and its load in the return direction. An attempt made to stop a rapidly rotating pulley, and to bring it to a high speed in the opposite direction, will convince anyone that there is often need for an excess of power above that required for ordinary work. At such a time the driving-belt of a planing machine is subjected to an extra heavy load, which can be relieved by the use of a balance wheel upon the countershaft. As to when a balance wheel is needed, depends upon the design of the machine. One type of machine has light pulleys, and a comparatively low-gear ratio, and with these a balance wheel is not much needed. Another type of machine works under similar conditions, and, with wide belts running at moderate speed, operates well by having the countershaft pulleys heavier than usual Still another type of planer has a high ratio of gears, narrow belts, and consequent high speed of the pulleys; and for such machines the addition of a balance wheel is very desirable.—**J. C. Steen,** *Amer. Engin. and Rlrd. Jnl., Vol. LXXVII, No. 12,* pp. 447-448.

Air Compressors.

A THEORETICAL survey of the working of air-compressors, from which conclusions are drawn as to the points on which their design should be based.—**E. W. Köster,** *Zeitsch. des Ver. Deutsch. Ing., Vol. XLVIII, No. 4,* pp. 109, 118.—*A. G.*

A Winding-Engine Problem.

IN this paper the author endeavours to show how simple methods may be used to solve fairly difficult problems of a practical kind, when they are properly applied. For the purpose of demonstration he assumes that a firm is asked to supply a winding-engine of the direct-coupled type. The engine is required to lift a load of three tons a vertical height of 200 fathoms in 30 secs. The author then explains the right way of attacking the problem; indicating a simple method by which all the really important force curves can be plotted in diagrammatic form. The final resultant curve has then to be obtained by adding and subtracting those forces which oppose and help the engine respectively, and the next step is to find the required engine power. The article shows that the possession of a few simple expressions and formulæ, and a sufficient knowledge of graphic methods, will suffice for solving all such problems.—**Anon.,** *Engineer, Vol. XCVI, No. 2502,* pp. 565-566.—*W. N. T.*

WORKS MANAGEMENT.

Manufacturing Costs and Profits.

THIS article is an extension of the modern scientific study of manufacturing into the province of general commercial management. The author applies the results of cost-finding methods to the ultimate questions of profit or loss in production, and demonstrates the nature of his system by the aid of a series of accounts, tables, and diagrams based on assumed values. A useful arrangement brings the whole series of comparative diagrams vertically in line, thus making it easy to follow the record for a given period. The work involved in the system is not great, and can be performed by the ordinary office staff; but it will greatly aid the busy man at the helm to a more comprehensive and accurate survey of the entire working of all the various departments, to a correct appreciation of their interrelation and interdependence, and to the location of the responsibility for good and poor results. It is applicable in any line of business or manufacture, whether on a large or small scale, so long as the operation can be reduced to comparison with some general factor, such as output or labour.—**H. Hess,** *Eng. Mag., Vol. XXVI, No. 3,* pp. 367-379.

WATER AND SANITARY.

Bacteriological Methods in Water Analysis.

THE decomposition of organic matter may be measured either by the material decomposed or by the number of organisms engaged in the process. The distinction between quantitative and qualitative methods is somewhat arbitrary. The gelatine plate is not only quantitative but also qualitative, and the dextrose broth test is quantitative as well as qualitative when applied to a series of measured portions of the water to be examined. In addition to detecting the presence of general organic contamination, the bacterologist can discover in polluted water semi-parasitic organisms whose presence indicates the presence of sewage. The tests used in defining *Bacillus coli* are not yet quite uniform. For example, Whipple has recently given 48 hrs. as the period for the nitrate, milk, and indol reactions, while 24 hrs. is the time employed in many laboratories for the two first, and 72 hrs. for the last of these tests. More serious than these variations is the failure to apply the colon test quantitatively to the examination of small samples of water. Colon bacilli are either wanting in good waters, or are so rare as not to be

found in the examinations of samples of 1 cub. cm.; but they are found in a majority of 1 cub. cm. in samples of water so polluted as to be dangerous for drinking. In an examination of a single sample of water, the attempt should be made to isolate colon bacilli and streptococci, and to work them out in detail. Often, however, some shorter method is desirable. Theobald Smith has pointed out that the dextrose broth tube furnished a rapid test, and it has since been established that organisms found in water, which at 37 degs. produce in 24 hrs. a good quantity of gas, made up approximately of two parts H to one part of CO_2, are almost always colon bacilli. The litmus-lactose-agar plate affords another method of examination which is capable of wide and helpful application, and which should not be neglected, particularly in view of the fact that the litmus-lactose-agar plate reveals the presence of the streptococci, which may be overlooked in the dextrose tube. The full bacterological examination of the future will consist of three parts—the gelatine plate count, the total count, and the count of red colonies on litmus-lactose-agar; and the study of a series of dextrose broth tubes for the isolation of colon bacilli and streptococci.—**C. E. A. Winslow** and **C. P. Hibecker,** *Techy. Quarty. Vol. XVI, No. 3,* pp. 227–239.

MISCELLANEOUS.

The Tonnage Laws and the Assessment of Harbour Dues and Charges.

THE Merchant Shipping Act of 1854 established the present method of measuring the tonnage of vessels. The consolidation of the laws relating to merchant shipping, which was accomplished by the Act of 1894, made some changes in the details of tonnage allowances; but as it did not alter the fundamental principles of measurement, comments on the tonnage regulations made in the paper are based on the law as it now stands under the Consolidating Act of 1894. The word "ton" has such a variety of meanings in connection with shipping that its derivative "tonnage" has acquired an undesirable vagueness. There is the ton of weight, the ton of measurement, the ton of displacement, the ton of burthen; also the registered ton, totally different from any of the others. The words "registered tonnage" are used to denote the internal capacity of a ship, and are supposed to express the internal space in the vessel in ton units of 100 cub. ft. Tonnage, as ascertained by the tonnage regulations of the Merchant Shipping Act, 1894, is of three denominations: (*a*) Gross tonnage, being the vessel's total internal capacity; (*b*) tonnage under tonnage-deck, being the internal capacity up to the tonnage-deck; (*c*) registered tonnage, being the net or official tonnage after the deduction from the gross of all allowances. The duty of directing and controlling the measurement of ships has been imposed by Parliament upon the Board of Trade, whose surveyors carry out the actual measuring and calculation of the tonnage of British ships. Although the tonnage regulations for the measurement of internal capacity are sound in principle, and have never been seriously objected to since their introduction in 1854, questions have frequently been raised upon the interpretations which the authorities of the Board of Trade have, from time to time, put upon the Act; first, as to what spaces shall be measured, and what spaces shall be exempt from measurement in the gross tonnage; and secondly, upon the deductions and allowances from the gross tonnage which are permitted by the Act in ascertaining the net or registered tonnage. The allowances contemplated by the Act of Parliament are of three classes: (1) spaces devoted to the accommodation and comfort of the officers and crew, and to the protection of deck passengers from exposure to the weather; (2) spaces occupied by the necessary appliances of navigation, and by certain arrangements which may, under special circumstances, tend to the safety of the ship; (3) spaces occupied by the ship's propelling apparatus. It is the third class of allowances which make the most marked differences between the treatment of sailing ships and steamers in respect of tonnage measurement, and gives scope to the ingenuity of designers, which, while it secures perfectly legal tonnages, sometimes makes such tonnages ridiculously small; this causes grave inequalities in the incidence of charges based upon tonnage. The paper explains in detail what is the law respecting tonnage measurement, and an appendix gives a number of illustrations of the actual tonnages of vessels, showing the irregularity which arises from the present law. As the Merchant Shipping Act of 1894 allows authorities who have power to levy tonnage rates upon ships to levy them upon the registered tonnage as determined by the regulations of the Act, it is natural that shipowners should take advantage of every device to reduce that tonnage to its legal minimum. There being no Imperial taxes upon shipping, the most important bearing of this clause of the Act is upon the dues and charges levied on shipping by the various port authorities of the United Kingdom. There can be little doubt that the original idea of harbour dues was a tax recognising the rights of the lord of the place; and, perhaps not unnaturally, it was levied in some supposed proportion to the apparent ability of the shipowner to pay it. This view has crystallised into the idea that harbour charges should be levied in proportion to the earning powers of the vessel, and it has been supposed that tonnage is a fair measure of that earning power. The author contends that this idea is feudal and antiquated, and that, even if it were not, tonnage is a false and inadequate measure of earning power. He believes that the only fair and reasonable basis for the assessment of harbour dues and charges is the nature and extent of the services rendered by the harbour authority to the particular vessel making use of those services. If this be right, it is neeessary to consider the nature of harbour services before a proper opinion can be formed as to how dues should be assessed. These may be broadly described as of three different kinds: (1) The provision and maintenance of a

safe and convenient waterway from the open sea to the point of loading or discharge; (2) the provision of safe and suitable quays for loading and discharging cargo, and for embarking and disembarking passengers; (3) the provision of special appliances and conveniences for special purposes. The cost of preparing and maintaining a waterway approach to the harbour, other things being equal, is probably proportional to the depth of the channel. The breadth of channel is governed by natural local conditions or by the volume of traffic to be accommodated, and not by the breadth of any individual vessel. It would therefore appear that for this part of the harbour service every vessel should pay in proportion to her draught of water. Quay accommodation is somewhat different. The cost of construction and maintenance is probably porportional to the height and length of quay-wall. A vessel's draught, therefore, is not a complete measure of the service rendered to her; her length comes into the question, and the service rendered would be more correctly gauged by the product of the vessel's length and draught. For reasons explained in the paper, it would perhaps prove more convenient to levy the quay-charge separately on the vessel's length and on her draught. It does not appear that the breadth of the vessel has much to do with this part of the service rendered by the harbour authority, except perhaps to a small extent in the case of enclosed docks, when it may somewhat effect the water area required for manœuvring the vessel, and to this extent have an influence on the assessment of her dues. The vessel's breadth may also have some effect by the width of dock entrances required, and these are points which it is hoped may be elucidated in discussion. Capacity may be said to affect the question of quay-area required for the reception of cargo, but the author is of opinion that this factor in the assessment of dues varies so much on account of special circumstances in each case, that the area of quay required should be relegated to the class of special charges for special purposes, and be charged for as a rent according to the area required and the length of time of occupation. Under the present system passenger accommodation is liable for dues, whether that part of the ship is in use on the particular voyage or not. It is possible, of course, that the port does provide facilities for passengers, in which case they should certainly be paid for when, and to the extent that, they are used. A tonnage charge, however, makes no such distinctions, and to this degree is inequitable; a suggestion, whatever it may be worth, is made for meeting this difficulty by a time and capitation charge. The author further points out that the unit of time for occupation adopted by most port authorities is so long that little distinction is made between the vessel which arranges for rapid dispatch, and so makes room for a fresh customer, and the vessel which uses the accommodation of the port up to the extreme limit allowed on one payment. The principle of payment for special appliances, according to the extent of their use, is already recognised in such a large degree that it needs little argument to justify its extension. It is recognised that harbour revenues, however derived, should be sufficient to pay working expenses, maintenance, a reasonable interest on capital outlay, and the accumulation of such a reserve fund as will provide for improvements from time to time as they may be necessary, to keep abreast of the requirements of the traffic. Probably this means, in most cases, a revenue at least equal to the present revenue. Any change, therefore, should first of all be so arranged as to conserve the present incomes of existing ports. At the same time, the charges on an "average ship" should not be higher than they are at present. It is evident that such a readjustment of charges involves a laborious investigation and exhaustive inquiry. The author confesses that he has but little hope of any beneficial reform from an amendment of the tonnage laws; partly because tonnage is an international subject, and the laws can only be altered with the approval and consent of most of the maritime nations of the civilised world; but also, and perhaps mainly, because he considers tonnage to be an unnatural basis for the assessment of harbour dues.—**H. H. West, M.Inst.C.E.,** *Proc. Inst. Civ. Engrs., Feb., 1904.*